OCTOBER 1961 Volume 199 Part 2



Established 1869
Incorporated by Royal Charter 1899

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JOURNAL OF THE IRON AND STEEL INSTITUTE

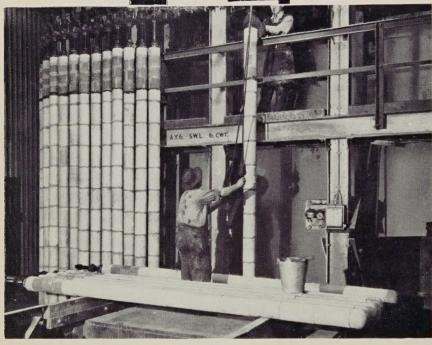
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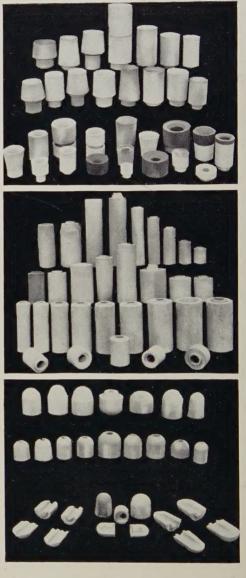


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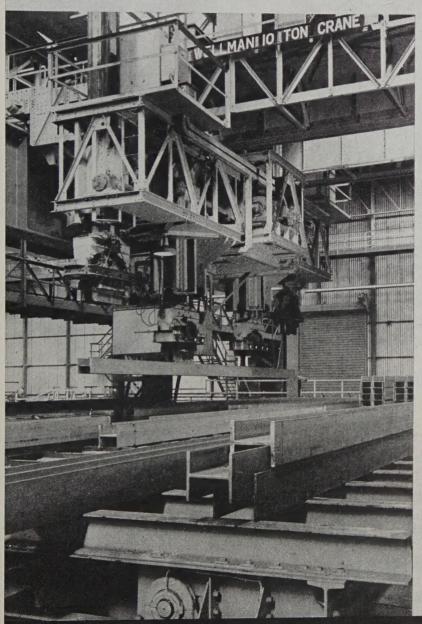
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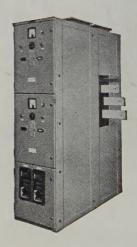


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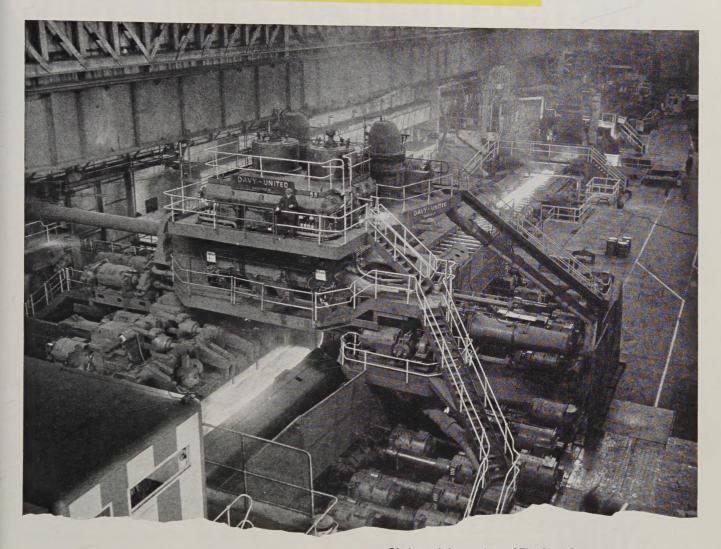
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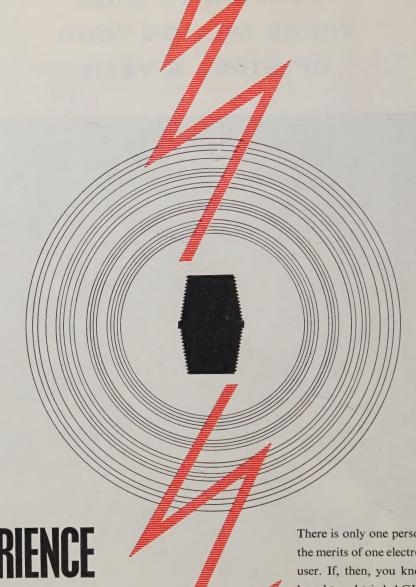
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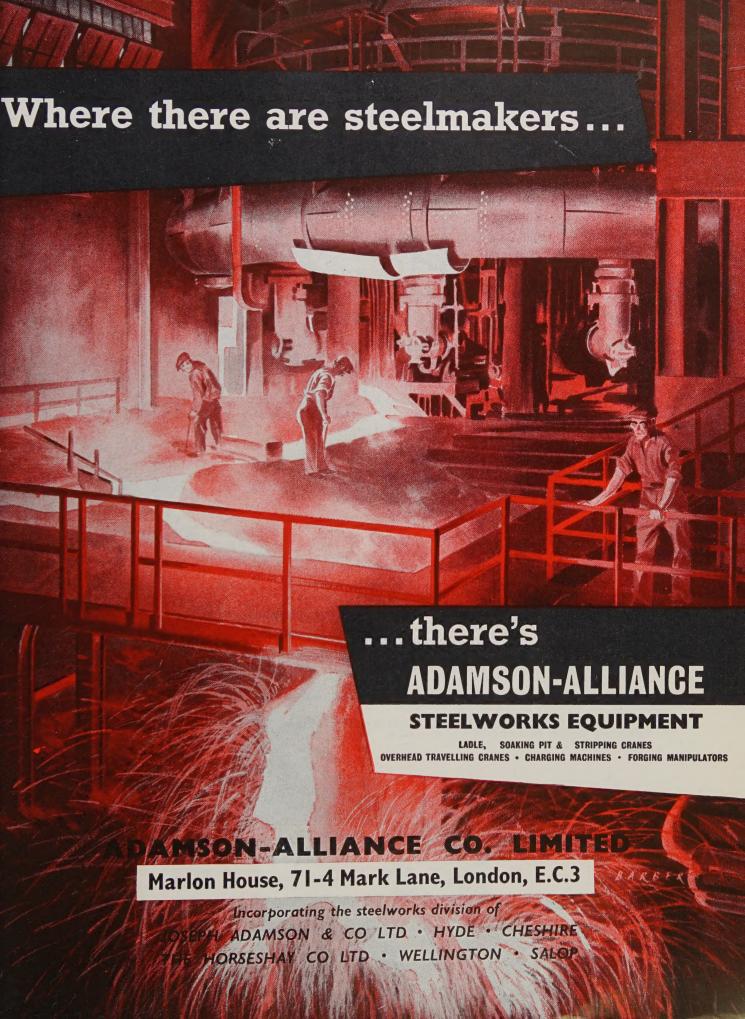


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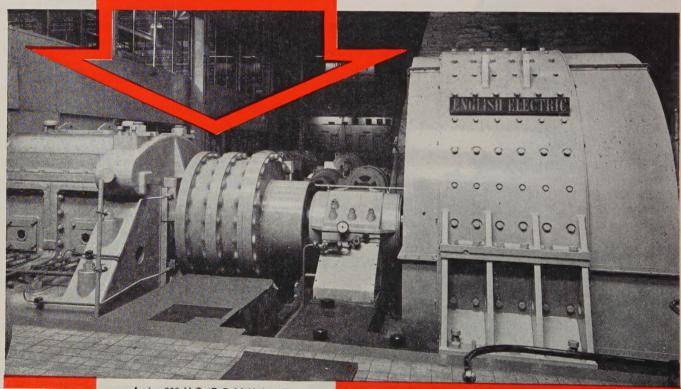
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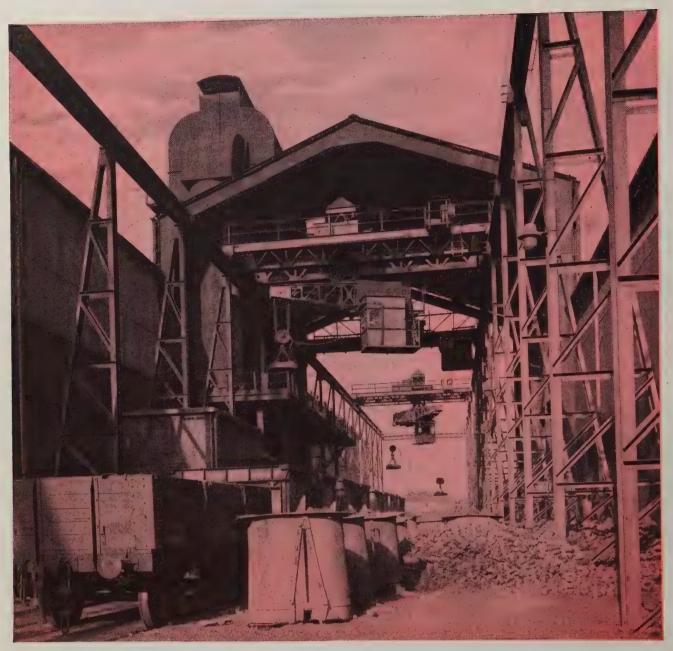
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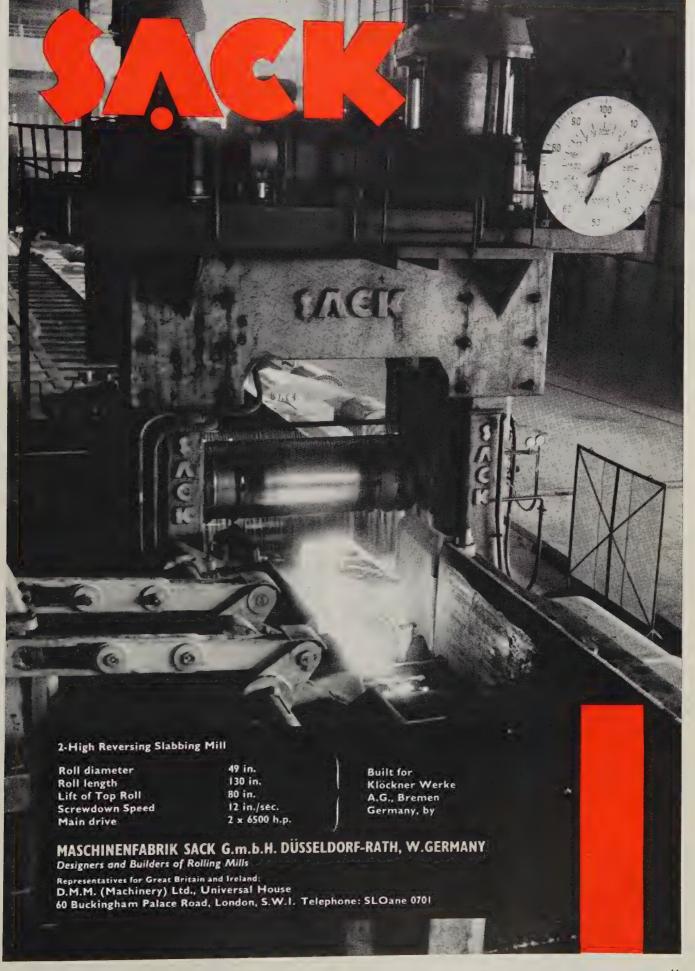
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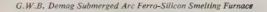
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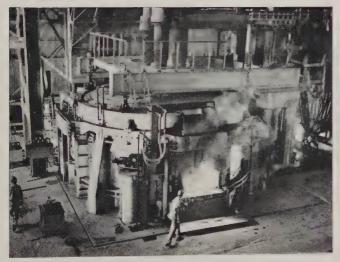
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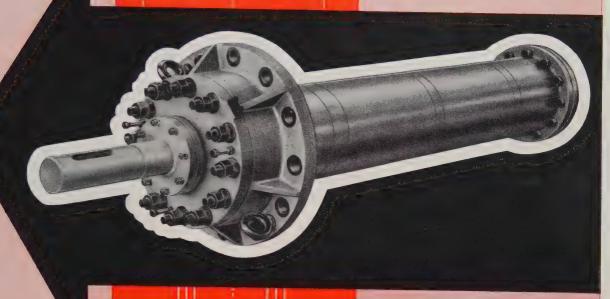
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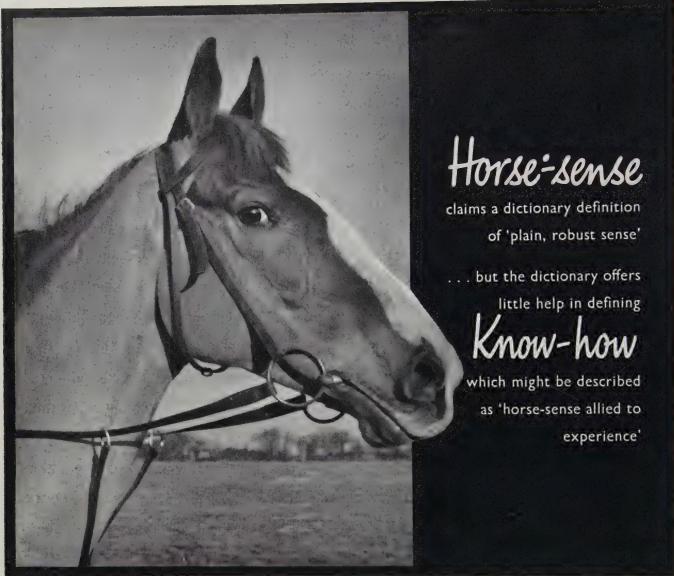
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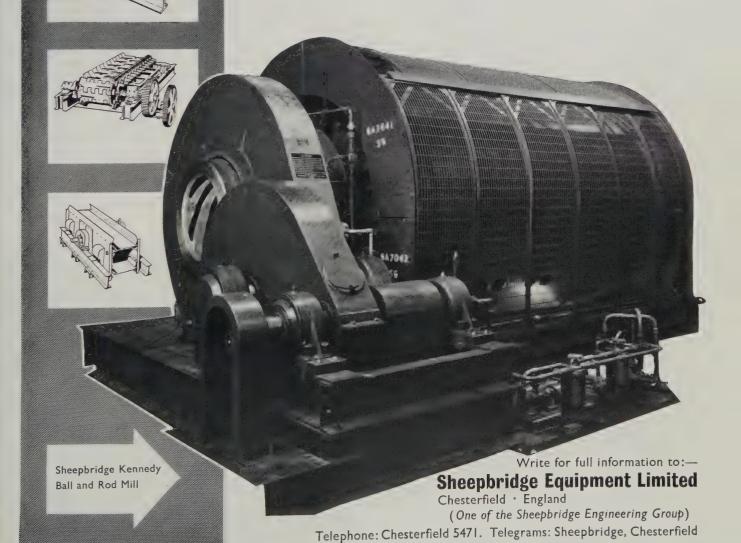


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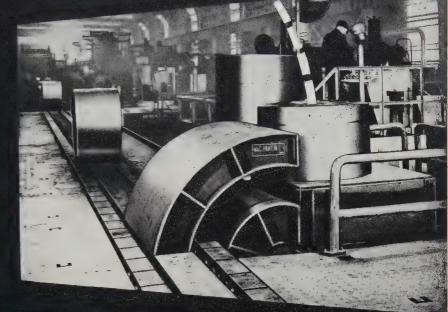




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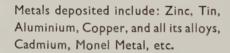
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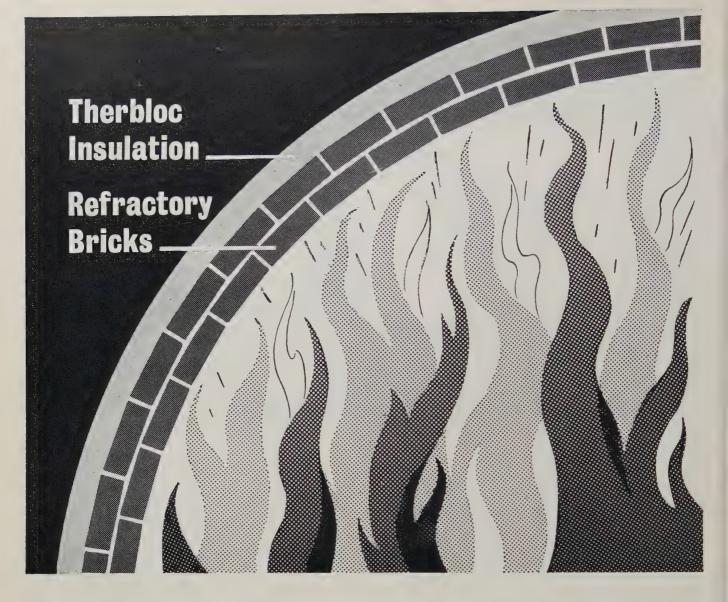
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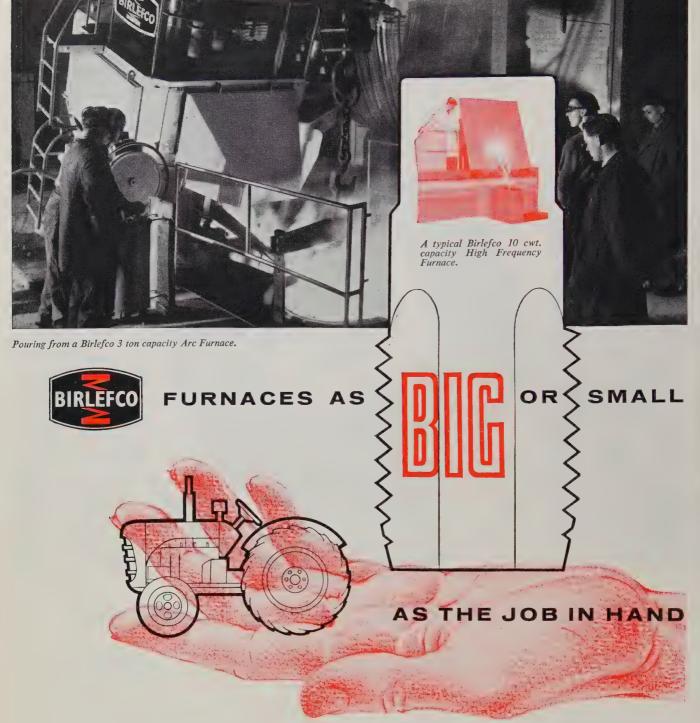
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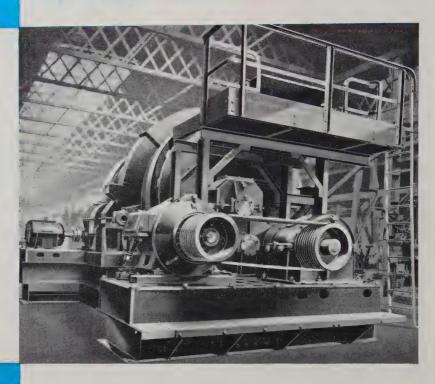
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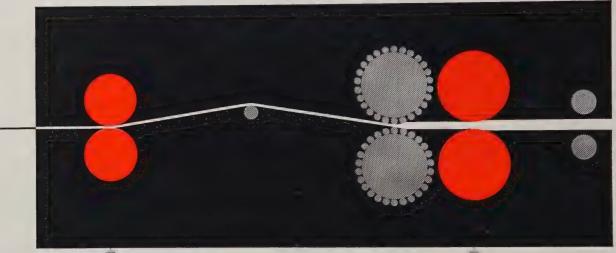
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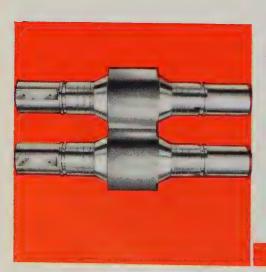


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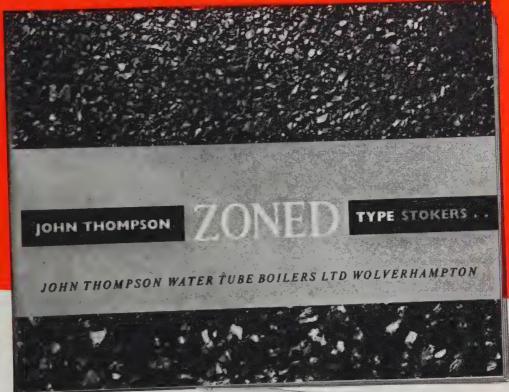


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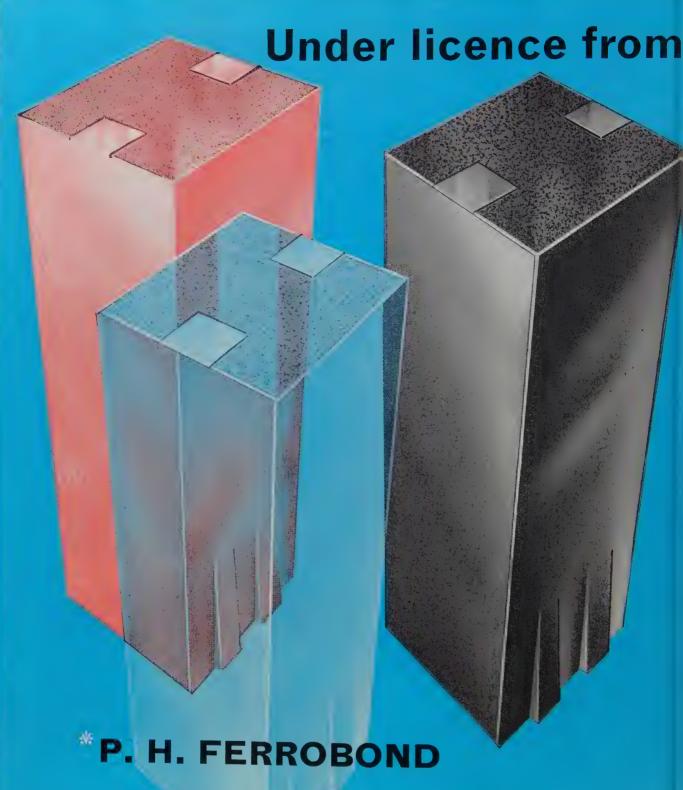
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190 Tons	12" Rib 9" Valley	250 Heats 75 Days	47,500 Tons	26	2.2%	12.6%	2
190 Tons	A11 12"	405 Heats 130 Days	77,000 Tons	25	62%	67%	2
200 Tons	15" Rib 12" Valley	488 Heats 196 Days	100,000 Tons	21	2.8%	6.6%	NONE
345 Tons	15" Rib 12" Valley	453 Heats 170 Days	157,000 Tons	38.5	10.4%	19.0%	2
400 Tons	15" Rib 12" Valley	298 Heats 186 Days	120,000 Tons	27	NIL	NIL	2

This chart shows comparative performance records in North America of six typical open hearth roofs. In each case the roof was constructed half-and-half of Lavino Ferrobond CMX 3" x 3" Roof Keys and Internally Plated 4½" x 3" Roof Keys.

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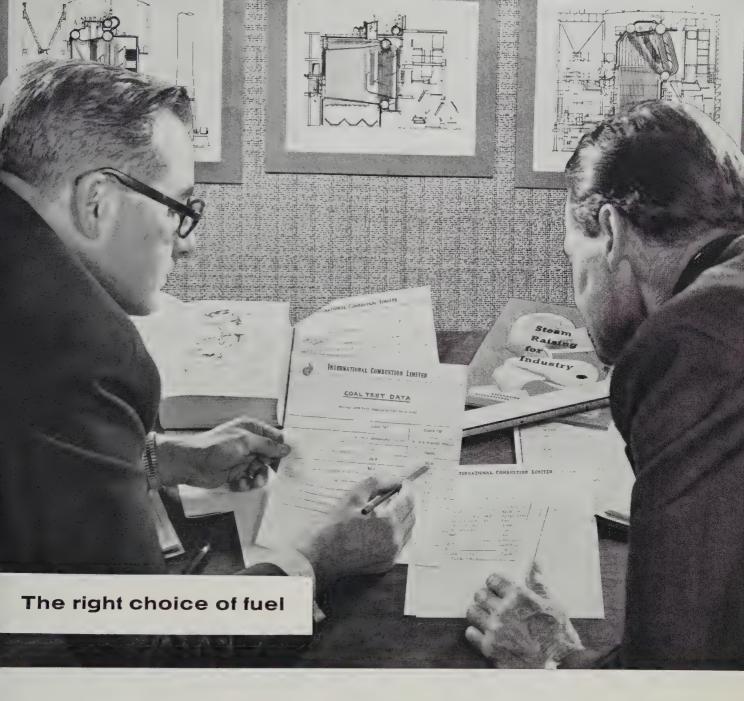
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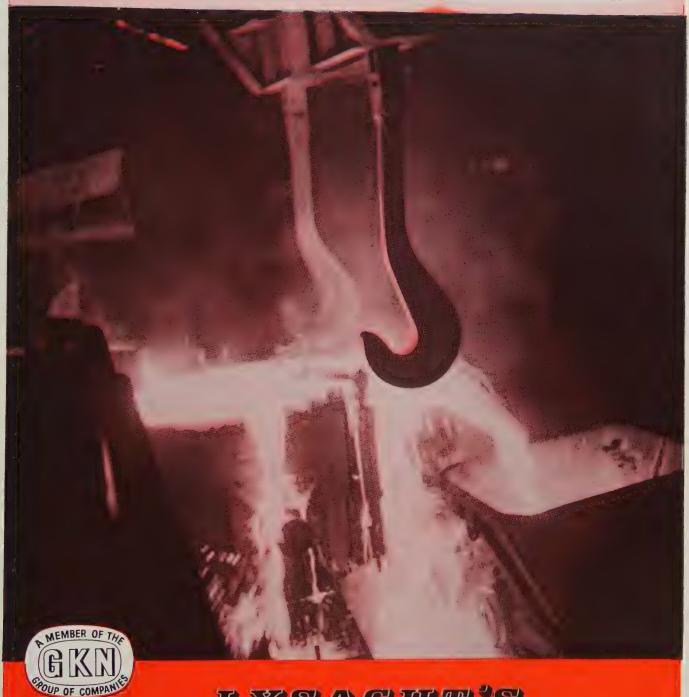
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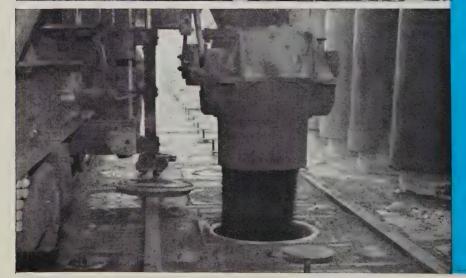
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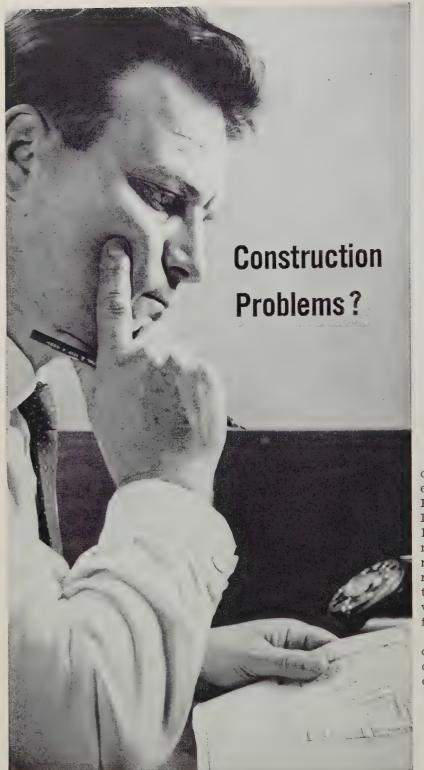
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#### SIR ROBERT SHONE, C.B.E., M.A., M.Eng.

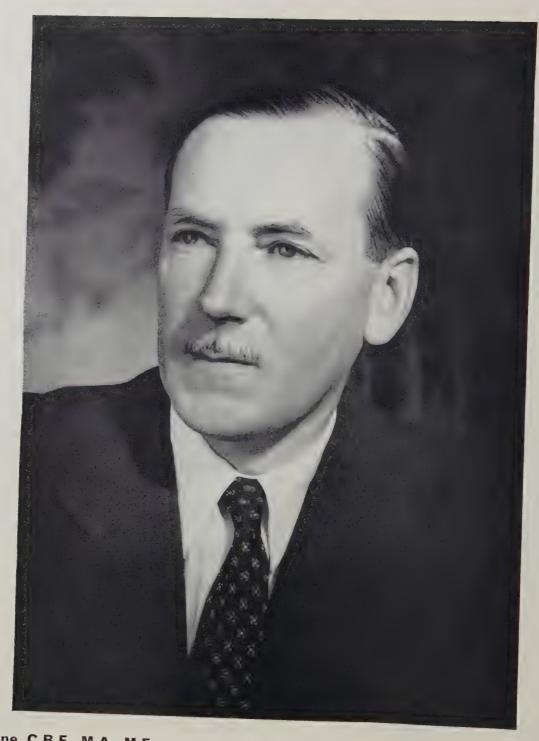
ROBERT SHONE was born in 1906 and was educated at Sedbergh School in Yorkshire. His family have been connected with the steel industry in Liverpool from the middle of the last century and before that they were engaged in building small boats on the Dee near Chester. Sir Robert graduated in Engineering at Liverpool University, and later trained with Stewarts and Lloyds and as a junior engineer with shipping companies, sailing to the Far East and North America. He then obtained a Commonwealth Fellowship for two years and studied economics at the University of Chicago.

Following a short period of lecturing at the London School of Economics, Sir Robert joined the British Iron and Steel Federation as head of their Economic and Statistics Department.

In due course he became Director of the Federation during the later years of Sir Andrew Duncan's independent chairmanship. Sir Robert was appointed Executive Member of the Iron and Steel Board on its formation in 1953.

He has taken an active part in general economic affairs, serving as Vice-Chairman of the Royal Statistical Society and as a member of the Executive Committee of the National Institute of Economic and Social Research. He is currently Joint Chairman of the Steel Committee set up under the Council of Association between the United Kingdom and the European Coal and Steel Community.

Sir Robert was created C.B.E. in 1949 and knighted in 1955. He has been a member of The Iron and Steel Institute since 1948 and was elected an Honorary Member of Council in 1961.



Sir Robert Shone, C.B.E., M.A., M.Eng. Honorary Member of Council

### Blast-furnace engineering development

D. R. Brown, B.A. and M. Adamson, M.B.E.

IT MAY WELL BE SAID that the development of the British blast-furnace has made more progress in the last 25 years than in any period of twice that duration in the previous history of the industry. This claim seems justified by facts. At the start of the period it was exceptional to find a furnace producing more than 500 tons of iron per day, or of a size greater than 18 ft hearth dia. Today it is less exceptional to find a furnace that can produce 1500 tons/day, and hearths around 30 ft are relatively plentiful. During these 25 years overall output in the UK has more than doubled, the output of individual furnaces has nearly trebled, and the coke consumption per ton of iron has been reduced by 30%. This is indeed progress, even though the ground covered had to a large extent already been explored in other countries, notably the USA. Nevertheless, from a backward position 25 years ago, Britain has now not only drawn level with the leaders, but can herself contribute to world progress.

In this context developments have a purely practical purpose; they must aim to improve the blastfurnace process or plant with the object of making more economically whatever quantity or quality of iron may be required. Development work is not the prerogative of any particular section, it concerns management, process technologists, and engineers, and each of these must have some general knowledge of the subject in which the others specialize. Plant designing engineers can initiate improvements which stem from knowledge within their own province. Plant operating technologists can seek to discover what is required to improve the operational functions of the furnace. Management must decide what production is required, what materials are available, and those responsible for expenditure must evaluate the true worth of each proposed development, taking into account what repercussions it may have in other sections of an integrated plant. If these are the central figures in what is truly a combined operation, they are not the only participants; makers of refractories, designers of electrical equipment, instrument manufacturers, and others have extremely important parts to play.

There is a distinct difference between the manner in which the engineer and the operator can approach their respective development problems. Whatever engineering work has to be done can be done according

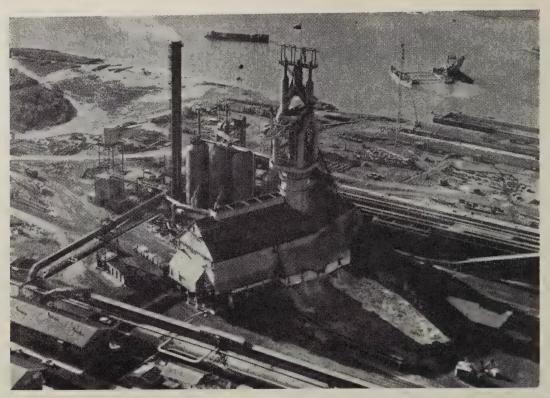
Manuscript received 17 July 1961. The authors are with Ashmore, Benson, Pease and Co. Ltd, Stockton-on-Tees.

#### SYNOPSIS

Blast-furnace engineering development is presented from the British point of view, seen against the background of events in this country, which may not wholly correspond with what has occurred elsewhere. Attention is confined to the period of the present generation and to some speculation on what direction future progress may be expected to take.

to established engineering criteria; the competent designer, by the proper application of his professional knowledge, can proceed with the certain knowledge that his objective will be achieved, but this is not so with the operator. Careful observations may lead him to believe that some change may benefit the working of the furnace, but he is conscious that anything he does may disturb what has aptly been called 'the chemistry of infinitely varying balances among conflicting tendencies'. He must proceed with caution because furnace conditions, in other respects, cannot remain constant, so the effects of his deliberate change may be difficult to disentangle from results brought about by other causes. Developments which have a bearing on the chemical process originate as theories and, though these may be endorsed by laboratory tests and thermodynamic calculations, there still remains the degree of uncertainty that discourages any violent leap into the unknown. It is thus inevitable that developments in this field can only move at a pace dictated by the careful and patient observations which are necessary to establish whether the theory was well founded.

The function of the engineer is two-fold: he can improve the plant and equipment by introducing better engineering standards and techniques or, as is more often the case, he can engineer the means to put into practice the ideas or requirements of operators and others. The expression 'engineering developments' must embrace both these functions and therefore it merges with other developments to which the engineer has only a secondary claim. Any attempt to foresee the trend of future developments also involves some knowledge of where technology may lead as well as of what motives actuate the engineer. The fact that developments may originate from more than one source does not really complicate the issue, though it points the need for very understanding co-operation. The guiding principles behind this work of development, and an idea of what engages current attention, can in a simplified form be expressed thus:



1 The Commonwealth's largest producer; 62 370 tons in one month; hearth 29 ft dia., 21 tuyeres, and 7 columns, electrostatic gas-cleaning plant, slag cast into pits

(i) use of new materials and new construction techniques as they become available (e.g. weldments; special steels; hard-facing; radiographic and supersonic tests; portal and tubular designs, etc.)

(ii) conservation of labour by the use of mechanical devices to replace arduous manual work (e.g. passenger and goods lift to furnace top; access to the cast-

house for tractors and fork-lift trucks, etc.)

(iii) elimination of human errors by introducing automatic controls (e.g. by pre-setting dials on a control panel, every function of furnace charging: weighing, hoisting, and movements of distributor, bells, stock-rods, etc., can be performed automatically)

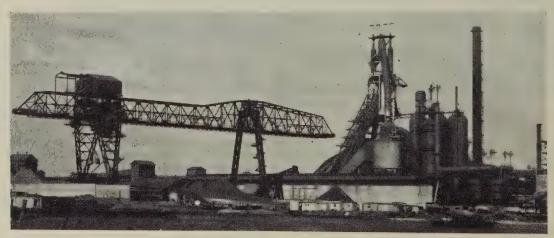
(iv) devising ways to reduce operational hazards to those employed around the plant (e.g. operating the clay gun, tap-hole drill, runner gates, and slag-notch stopper by remote control)

(v) affording precise knowledge of conditions by full instrumentation (e.g. hearth and stack pyrometers; continuous gas analysis; measuring lining

wear with isotopes, etc.)

(vi) building larger units to increase production (e.g. furnaces with 32 ft hearths, 27 tuyeres, two iron notches, and two cast houses, to operate at 30 lb/in<sup>2</sup> top pressure, are already contemplated)

(vii) aiming at maximum availability by devising means to reduce time lost when effecting repairs and



2 Ore stocking bridge, 18 tons grab, 1500 tons/h, amplidyne control of hoist and cross-travel movements, hydraulically operated rail clamps



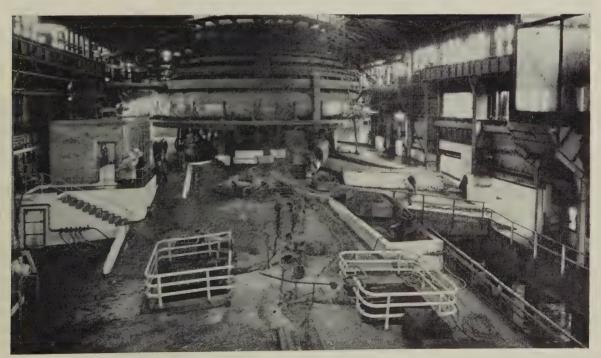
3 Unloader with 15 tons grab arranged to twist through 360°, and discharge 1500 tons/h

renewals (e.g. built-in lifting appliances and access platforms to facilitate valve changes; twin-motor hoists that can operate on one motor; using castables to repair mains; less vulnerable cooling systems, etc.) (viii) doing everything possible to prolong campaign

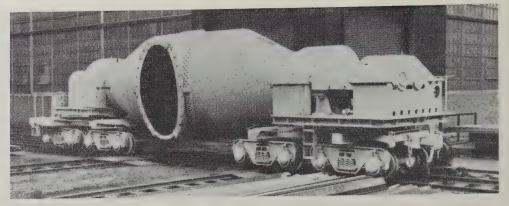
life (e.g. carefully planned reline programme, with all

requisites and special tackle to hand, use of carbon and super duty linings, etc.)

(ix) increasing efficiency by conditioning raw materials so that they will most readily respond to the chemical reactions within the furnace (e.g. crushing, screening, bedding, sintering, pelletizing, etc.)



4 Blast-furnace, UK, hearth 31 ft dia., carbon lined to lintel, jacketed bosh, internal cooling staves, 24 tuyeres, 8 columns, only 52 ft of iron runners



5 200 tons capacity hot-metal mixer ladle

(x) increasing economy by making beneficial use of flue dust and surplus gas (e.g. reconditioning flue dust by sintering or pelletizing; avoiding gas leakage at furnace top, etc.)

(xi) decrease wasted effort by minimizing runner scrap and ladle skulls (e.g. using 200–300 ton ladles shortens runners and reduces skulls)

(xii) creating the conditions that will accelerate the furnace reactions (e.g. by artificially increasing the gas pressure within the furnace stack)

(xiii) ascertaining the extent to which humidifying the blast will benefit the furnace (e.g. by injecting steam into the blast and increasing stove temperatures to offset heat lost in dissociation of H<sub>2</sub>O)

(xiv) ascertaining the extent to which expensive metallurgical coke can be replaced by less costly fuel, preferably injected at hearth level. Success in this direction would not only decrease direct costs but would increase production by making available more space within the furnace for ferrous materials

(xv) ascertaining the value of enriching the oxygen content of the blast, not only as a benefit within itself but also as an essential corollary to fuel injection and blast humidification.

Some of the features on this list have a time-honoured ring, some may seem commonplace, but a careful look around a 1961 furnace plant will disclose improvements to many details which viewed collectively are very impressive. It would be purposeless to describe every engineering development of recent years, some are relatively uninteresting, some could each be the subject of a separate paper. It is hoped that the accompanying illustrations, with their captions, will convey a general impression of what has been done, especially if the selection of 'engineering developments' is taken as representative of the whole.

#### HIGH TOP PRESSURE OPERATION

This provides an admirable example of collaboration: technologists foresee benefits in artificially increasing the gas pressure within the furnace: the engineer contrives the equipment to produce the desired conditions. Though the engineer neither initiates the development nor passes judgment upon the results, the process depends upon the efficacy of his work. There are several problems to be overcome. Gas leaks at the furnace top that are a nuisance at low pressure become a destructive menace at high pressure. A large bell cannot open against a force that can easily exceed 150 tons. There must be the means to revert to normal

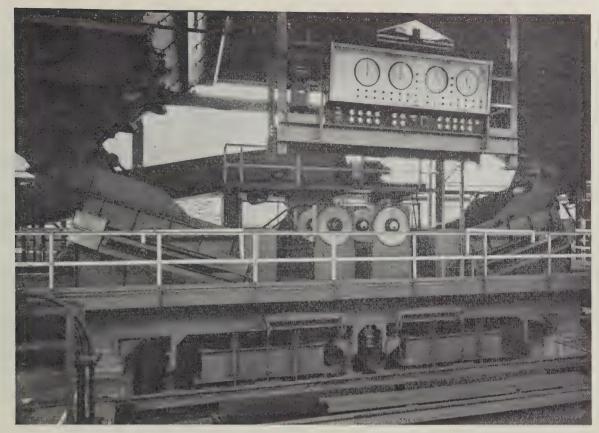
at a moment's notice. The equipment must be dependable and not add to the furnaceman's worries.

Gas leaks have been suppressed by one-piece hoppers and hard-faced bells, by improved distributor seals, by stock-rods enclosed in gas-tight sheaths, and by glands between the bell rods. A restriction in the gas main, the septum valve, creates the requisite back pressure. This valve is inserted after the primary washing-towers, sometimes after the final cleaners, where conditions allow it to respond to the control of a pressure regulator. Bells are enabled to open by equalizing the pressure above and below. The valves to do this must be inter-connected with the automatic charging control; the space between the bells is then pressurized before the large bell opens, and the contained pressure must be released before the small bell opens. Bleeder valves are a tough proposition; a leakage of hot dust-laden gas would be most destructive, yet they must be a self-operating safety vent against excessive pressure; the furnace operator must also be able to open them at will.

To solve problems that are novel to the blastfurnace, the engineers have been able to borrow from experience in other industries and a very successful system has been developed in the UK. Hydraulic power is used as the main motive force, the valves being controlled electrically. In early installations

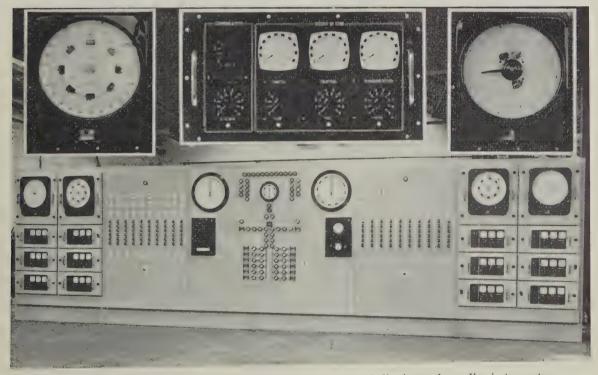


6 Stockhouse with sinter automatically screened and charged to skips, without attendant or scale car

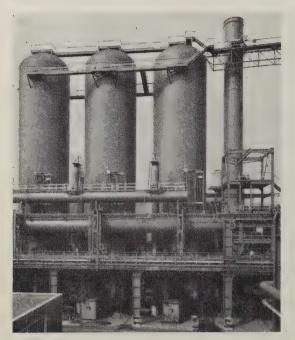


7 Automatic weighing equipment for coke and sinter at skip pit

bleeder valves opened inwardly and the pressure helped to hold them closed; now a hydraulic cylinder ensures that an outwardly opening valve is kept tightseated, yet if anything fails, its function as a safety valve is not impaired: it yields to excess pressure. The bleeders are actuated by pressure-operated switches,



8 Automatic charging furnace programme panel, with 'inset' weight selection, indicating, and recording instruments



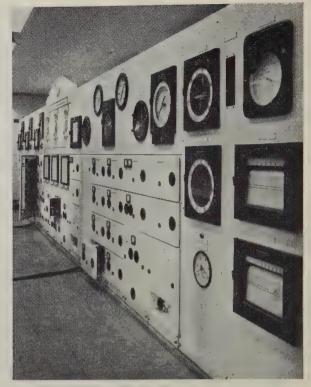
9 The largest UK stoves, 28 ft 3½in dia., 140 ft high

and are usually set to open in sequence; they are also under direct push-button control from the panel in the cast house.

It is beyond the purview of this paper to discuss the merits of high-pressure operation, but as an engineering development the innovation that once gave rise to some misgivings is now regarded as a welcome and docile addition to the means available to the operator for controlling the working of the furnace. The British-designed equipment is already being used on 21 furnaces in nine different countries.

#### AUTOMATIC STOVE CHANGING

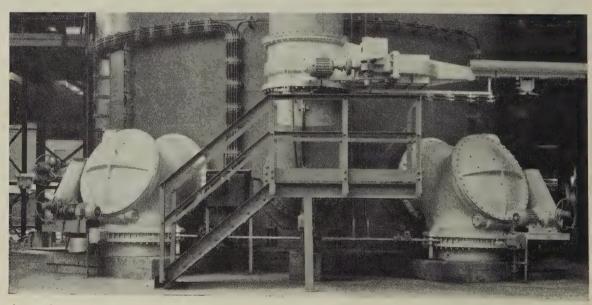
For many years, systems have been in use on the Continent for making stove reversals, from 'on gas' to 'on blast'. by automatic means from a central control



10 Automatic stove changing control panel, all-electric system

point. Many furnacemen, notably in the USA and the Commonwealth, regarded this as an unnecessary elaboration, but circumstances are now causing a change of mind. The use of sinter, humidified blast, oxygen enrichment, or oil injection all have some influence on the readiness of the furnace to accept higher-temperature blast. There is already enough evidence to suggest to the builder of a new plant that blast temperatures approaching 2000°F ought to be attainable as they may be in common use in the near future.

Straight-line temperatures in this range can be



11 Automatic stove changing valves, UK, all-electric system

reached with orthodox stoves only if refractories in the hottest zones are able to withstand flame temperatures in the region of 2400°F, and if the 'on blast' periods are foreshortened by more frequent stove changes. Thus the time taken to carry out a stove change becomes increasingly important, and can be brought to a minimum only by employing a method that cuts out the time lost in operating valves by hand. There is a limit to the speed at which stoves can be changed, for turning blast into a large empty stove will cause a sharp drop in blast pressure almost equivalent to a furnace 'check' unless this is done gradually.

It is conceivable that a high-duty recuperator may eventually be developed that will supplant the conventional stove arrangement but until that time comes it is likely that automatic stove changing will become standard practice. There are well proved systems available, the most common of which employs air cylinders to apply the requisite motion, the sequencing valves being operated electrically from a central panel. Installations of this sort are quite reliable though they do depend upon a lengthy and complicated system of air piping which some may think to be vulnerable. Later installations use a torque limiting drive, which allows an electric motor to exert a given torque. The essence of the problem is to apply a limited motive force to a valve, so the paddle will move only when the pressure difference on either side is not excessive, i.e. in correct stove changing sequence. The compressed air cylinder would do this, but a motor driving through normal gearing could exert excessive torque and perhaps incorrectly move a

valve. Today, with the new coupling, the electric drive has the same characteristics as the pneumatic system and can be made less vulnerable.

#### **AUTOMATIC CHARGING**

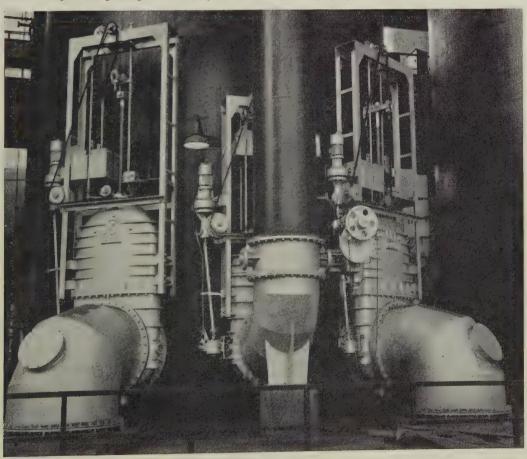
It is not long since the automatic sequence control of skips, bells, and distributors, etc., was hailed as a major innovation; though the system was still subject to the human inaccuracies of the scale-car operator. Now completely automatic charging is established. This development was accelerated by the use of selffluxing sinter which reduced the varieties of burden to be charged.

Preselected skips of material can be selected on the control panel, which is located in a convenient position, each load being made up from individual pre-weighed charges from one or more of the material bins, the total weight of each skip charge being checked in the weigh hopper. The charging is interlocked with the stock rods, so that once the burden sequence is established the charging continues automatically.

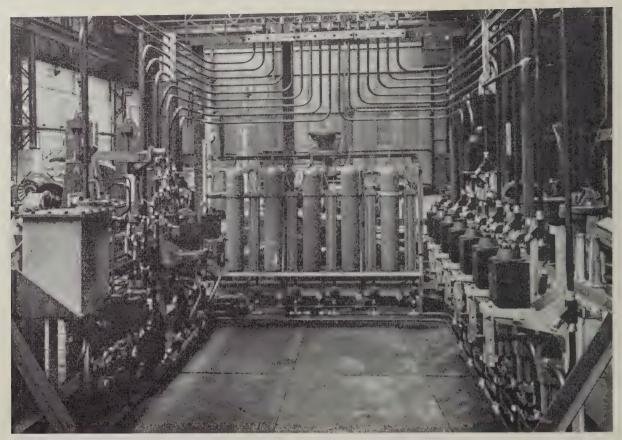
The next natural stage will be to group all instruments and stove controls and charging boards in a central area convenient to the furnace management; not disposed over the stove block, cast house, and stock house.

#### INTERNAL TRAFFIC, ROAD AND RAIL

Not many years ago rail transport was the only feasible way to handle the heavy traffic around a blastfurnace; in consequence the arrangement of the plant was largely governed by the need to conform with



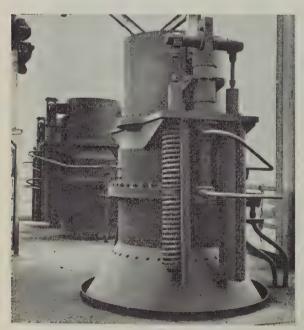
12 Automatic stove changing valves, Germany, all-electric system



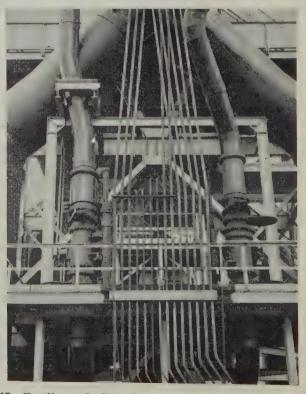
13 Shop assembly of hydraulic-electric control unit before installation

rules which must be observed in laying out tracks. The large road vehicles that are now available open fresh possibilities when new plants are planned. If slag is cast in pits and loaded by diggers, everything except hot-metal ladles can be handled by road transport: slag, flue-dust, cast-house supplies, etc. The man-

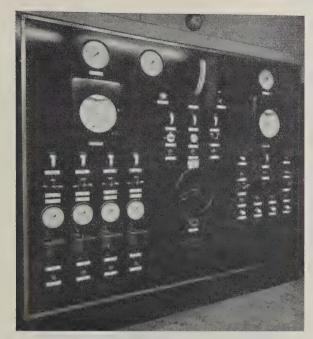
oeuvrability of these vehicles allows them to negotiate sharp curves, to turn, reverse, and enter areas in-



14 Hard-faced bleeder valve, outward opening and closing by hydraulic power



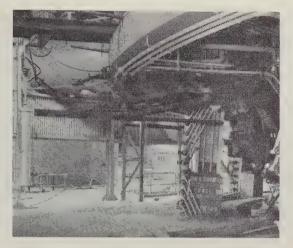
15 Equalizer and relief valves, sequenced with charging control



16 Pressure selecting and control panel

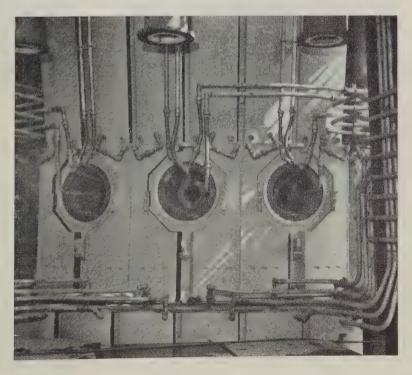
accessible to rail traffic; this freedom permits the plant to be arranged without deferring to the inflexibility of rail tracks.

These are a small selection of developments but sometimes painstaking effort has proved abortive; the Radcon furnace top was a well-conceived attempt to correct the uneven distribution of materials in the furnace; but ore crushing and grading so far reduced the evil that this intricate contrivance was deemed unnecessary. The venturi top, designed to reduce flue dust losses, produced no very significant results and being ill-adapted to carry the heavy top hamper, it

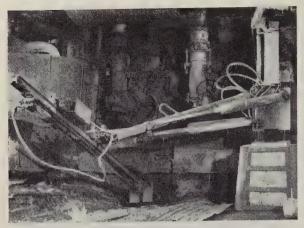


18 Automatic slag notch stopper, in 'out' position, showing full headroom to cast house floor

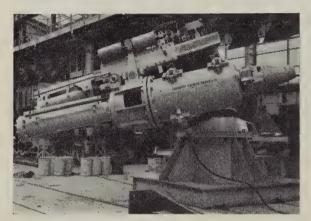
failed to find favour. Sometimes ideas have been developed to meet unique conditions and, though highly ingenious, have little application elsewhere. An example of this is the furnaces that were charged by belt conveyors when orthodox skips could not be used because of congestion in the area. Belt charging will be used at a new Continental plant, a decision which will surprise a multitude of furnace engineers. Conveyors are no new invention; generations of engineers have examined and re-examined the pros and cons of belts v. skips and, throughout the ironmaking countries of the world, all have come to the same conclusion. In any case the innovation will not further the art of making iron, for a well designed skip system leaves little to be desired, and can hardly be excelled for reliability and flexibility; it also permits orthodox distribution of the materials.



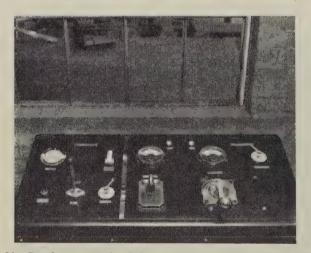
Clean channel cooling on hearth, tuyere, and bosh jackets



19 Taphole drill remotely controlled from the cast house control station

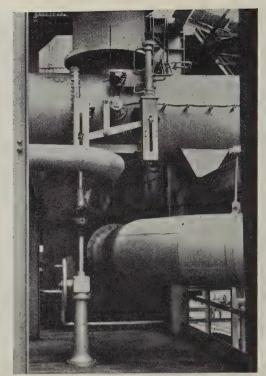


20 15 ft<sup>8</sup> clay gun with all-hydraulic drive and no gearing; exerting nozzle pressure up to 850 lb/in<sup>2</sup>

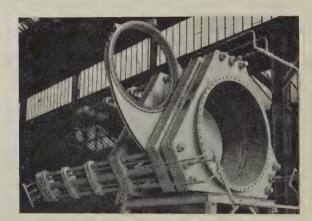


21 Cast house control pulpit, combining hydraulic snort valve and clay gun controls

These generalizations are not complete without reference to controversial developments. A good example is the query whether it is wise to rely upon the furnace structure to carry the loads imposed by the top gear (bells, hoppers, distributor, off-takes, etc.), loads which become increasingly formidable as furnaces grow bigger. It is no great problem to support these loads in the customary manner, and even to



22 Snort valve, showing hydraulic cylinder with stand-by manual control



23 Double-acting thermal expansion goggle valve, with detachable seats, designed for high-pressure operation

provide a wide margin of safety; but the designer's work is based on the known properties of the steel used in construction and takes no account of how far these properties might be destroyed by excessive heat. It is conceivable that a furnace, with a badly worn lining, might by neglect be allowed to become seriously overheated in the stack until the platework was no longer able to support the load, despite whatever safety factor was used. The collapse of the shell, with all its supports, would be a major catastrophe which could be avoided if the weight of the furnace top was carried separately on a structural steel framework, apart from the furnace and unaffected by furnace heat. The cost of this safeguard would not be wholly insignificant and, expressed bluntly, its purpose would be to guard against abuse. Experience on hundreds of furnaces may suggest that it is unnecessary, but should the risk of disaster, however slight, be ignored? Also, if this precaution against a remote hazard is thought advisable, how far ought the policy to be pursued against all the hazards that neglect or incompetence might create? The answer is most elusive: the designer will despair if his work must cater for abuse; the furnaceman will welcome the safeguards but resent the implications; the finance comptroller will deplore the additional cost; while only the most conscientious contractor would feel impelled to oppose whatever costly elaboration his client desired.

As has already been mentioned, this paper is not a detailed description of every recent engineering development. Some of the more novel examples are illustrated pictorially, and it is hoped that these will convey a general impression of the changes that have

been introduced in recent years.

It is important that everything possible should be done to foster development work in the future; how can this best be done? First, leaders in the industry must instil in others a desire for progress by showing this quality in themselves. Everyone concerned with operation must avoid complacency, and act in the belief that even the best results are open to improvement. Engineers and plant designers must realize that their proudest achievements will, 50 years hence, appear no more impressive than those of 50 years ago appear to the present generation; there is still much to study and much to learn. There is, too, a distinction between the engineers on the staff of a works and those in firms specializing in furnace design and construc-

tion. The former have many functions and are concerned with things from coke ovens to finishing mills; the opportunity for them to take an intimate part in building a new blast-furnace is rare; it occurs perhaps once in five years. Their confrères, wholly occupied on plant construction, are able to concentrate their attention upon this one subject alone; new projects may come their way perhaps three times a year. Their experience derives not so much from the exercise of their own talents as from the fact that their work entails detailed and purposeful discussions with others not only in the UK, but in very many overseas countries. This liberal education teaches them to value what they learn from others and gives them a wide and varied knowledge. It may be observed that, if these specialist organizations are to survive and flourish, they can do so only through the patronage of the industry they serve.

#### **ACKNOWLEDGMENT**

This commentary would be incomplete if credit were not given to BISRA for the part they play. The interchange and spread of knowledge is vital to progress and there could be no better catalyst than BISRA to accelerate the process with their willingness to collaborate, their conferences, and their publications.

The authors offer their grateful thanks to friends and associates in many lands who have shared with them their thoughts and ideas on this enthralling

subject.

#### Fuel-oil injection in a blast-furnace

P. Hazard

#### WHY INJECT FUEL OIL INTO A BLAST-FURNACE

IF THE BEST is to be obtained from a blast-furnace, considerable attention and care from the operators is necessary. Burden preparation nowadays requires as much supervision as the blast-furnace itself.

The blast-furnace operator understandably asks why matters should be further complicated by the injection into the furnace of this evil-smelling, viscous,

and inflammable product called fuel oil.

This paper will have achieved its purpose if these doubts are allayed. Fuel injection, properly executed, raises no additional problems; on the contrary, the resultant improvement in furnace operation and iron quality is one of the most interesting aspects of fuel injection in the furnace.

It should be said at once that there is no justification for general injection of fuel oil into blast-furnaces. In practice it is not worthwhile injecting fuel oil (or natural gas or coke-oven gas) into a furnace which readily accepts the hot blast at the maximum temperature which can be given by the stoves. By 'readily accepting' we mean that it is not necessary to check

#### SYNOPSIS

Reasons for the injection of fuel oil into a blast-furnace are discussed. The necessary equipment is described. Factors governing the choice of fuel oil are given. Results obtained by the injection of fuel oil in practice are detailed; and instructions for operation and safety are outlined.

the furnace, nor to inject steam into the blast to facilitate the descent of the burden.

On the other hand, if steam is injected, if the furnace must be checked regularly (leading to loss of production), or if the stoves are not used to the maximum, there is a clear case for oil injection. A short questionnaire is presented below; using this it is easy to calculate the amount of oil in a particular case and the benefit which can be achieved.

Questionnaire with a view to oil injection

- (i) coke consumption per working day
- (ii) average blast volume at the tuyeres (m³/h)
- (iii) average blast temperature over the last three months

Manuscript received 24 July 1961. The author is with Société des Aciéries de Pompey.

- (iv) maximum temperature which can be given by
- (v) how often are stove changes made?
- (vi) is there a third stove available? If so, what blast is possible?
- (vii) number of normal tuyeres

(viii) iron make per working day

(ix) is steam added to the blast? What is the average amount added per m<sup>3</sup>?

Explanation of these calculations

Average blast temperature If the average blast temperature (iii) is very close to the temperature which can be given by the stoves (iv) and, if no steam (ix) is added, fuel injection is not worthwhile.

Determination of the maximum possible temperature It will be (iv) above if the stove changes are made every half hour and if there is not a third stove.

It will be higher than (iv) if the changes are made hourly or two-hourly.

By changing from two-hourly to half-hourly stove changes, a temperature increase of 50°C is possible; from one-hourly to half-hourly, it is 20°.

If there is a third stove, temperature (vi) is the maximum one to be considered.

It should be noted that the extreme regularity of operation with oil injection means that the maximum blast temperature can be used without the necessity of a safety margin.

Amount of fuel to be injected Amount of fuel (a)/m³ of blast= $\Delta t \times 15/100 + \Delta v$  g, where  $\Delta t$  is the difference between the maximum possible blast temperature and the average temperature (iii), and  $\Delta v$ =steam added, g/m³ of blast.

Experience at Pompey (extending now over two years) has shown that for each 100° increase in blast temperature 15 g of oil/m³ of blast can be injected.\* On the other hand, steam can be replaced by heavy fuel oil almost pound for pound as has been verified at Cornigliano. Amount (b) per hour: multiply the figure (a) above by the hourly rate (ii).

Number of injectors The maximum number possible provided the oil rate does not fall below 50 kg/h per injector.

Up to 175 kg/h can be reached without difficulty. The number of injectors must be a divisor of the number of normal tuyeres so as to distribute them uniformly around the furnace.

Calculation of the improvement in coke rate (x) Work out the quantity of oil/ton of iron (oil/d divided by the daily iron make (viii)). The improvement in coke rate is roughly double the amount of oil/t† of iron.

Increase in iron make B=(I/I-X)-1=x/I-x for a given daily coke consumption.

If the wind rate cannot be increased, the increase in production, %, is B/2.

It must be remarked however that the maximum temperature of the blast acceptable by the furnace without injection of fuel oil generally tends to be underestimated, because of the desire for smooth furnace operation, even if this means a slightly higher coke rate. Because of this, it is not always necessary to

\* Throughout this paper 'ton' indicates the metric ton, abbreviated 't'.

inject the whole of the calculated quantity of oil to maintain smooth furnace operation. This is probably why our figures are a little lower than the theoretical figures of M. Cordier.

As far as the replacement ratio coke/fuel oil is concerned, which we have taken as 2 in our calculations, this coefficient varies from 1·8 (at Ougrée and Cornigliano) with a high percentage of sinter, to 2 (at Usinov Louvroil) with screened ore, and to 2·4 at Pompey with unprepared (0·250 mm) ore.

It must be mentioned that if more fuel oil than necessary is injected (e.g. by underestimating optimum hot-blast temperature without fuel oil), these coefficients are lowered automatically.

#### GENERAL

Discussion will be limited to installations where oil is properly used in the blast-furnace, i.e. those installations where 1 kg of oil replaces at least 1.7 kg of coke.

The injection of oil into a blast-furnace is made through the normal tuyeres, i.e. through tuyeres for the intake of hot blast. The injectors are about 2 m long and it is necessary to prevent the oil becoming coked before it is blown into the furnace: on the other hand, it must be atomized for the best possible combustion.

The fuel pipe is therefore enclosed in a second pipe. Compressed air circulates between these two pipes; this plays two roles: (a) it cools the oil, and (b) it atomizes the oil at the outlet of the injector.

Some systems even specify a third co-axial tube which acts as a protecting screen: this will be referred to later.

Figure 1 shows the arrangement for injecting light fuel oil into Pompey's no.3 furnace. The same arrangement is used for the injection of heavy fuel oil into no.4 furnace.

It is designed in such a way that the fuel oil cannot enter the compressed air circuit should the nozzle be obstructed; furthermore the central feed pipe for the oil can be extracted and replaced without having to dismantle the whole of the assembly outside the tuyere and without cutting the wind.

#### NECESSARY EQUIPMENT FOR INJECTING HEAVY FUEL OIL INTO A BLAST-FURNACE

It is necessary that the oil injected into each tuyere is suitably converted into CO and  $H_2$ , and above all without the formation of carbon black.

The carbon black drawn in by the gases is deposited with the fines of the charge (ore fines, coke fines) along the walls and thus encourages the formation of scaffolds in the stack. These are not solid scaffolds; they become detached and if proper precautions are not taken, there is considerable cooling of the iron.

In spite of such incidents, the chemical quality of the iron remains good although the silicon is very low; this is due to the sulphur partition between slag and metal which with oil injection is very high.

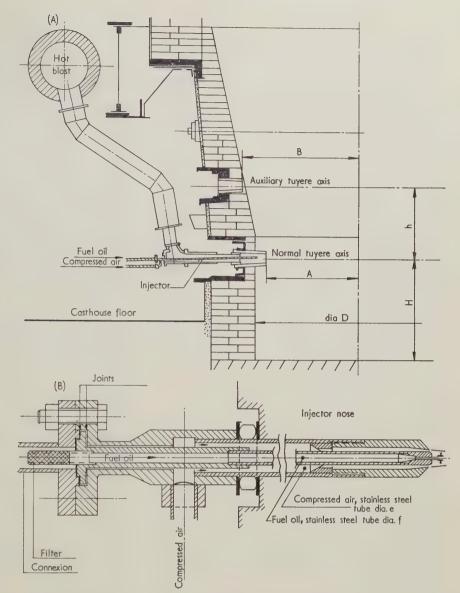
The equipment will then be adjusted to obtain a flow of oil, carefully controlled both as to rate and according to the location of each tuyere.

#### Requirements

No pulsation

An even flow of oil without pulsations is essential at the outlet of the injector; otherwise the quality of the

 $<sup>\</sup>uparrow$  The calculations of M. Cordier (IRSID) give 17–20 kg of oil per  $100^\circ$  and  $1000~\rm m^3$  of blast on the one hand, and 1·4 kg of oil in place of 1 kg of steam.



#### 1 Atomizing injector (patented)

atomization obtained with the compressed air would be diminished. If a system therefore of feeding the injector by means of volumetric pumps is used, it is advisable to plan the circuit thoroughly so that all pulsation has disappeared at the outlet of the injector. Sufficiently long pipework acting as a 'shock-absorber', for example, might succeed.

Ratio: oil flow/wind rate

Theoretically the temperature increase of the blast and the wind rate determine the amount of fuel to be injected. In practice, certain deviations from this rigid principle can be tolerated, provided they are of short duration. An installation that would permanently maintain for each tuyere a constant blast/oil ratio would be too complicated and would not bring any significant advantage compared with a more simple installation.

There are two points of view to be considered: safety, and the formation of carbon black.

Safety From the safety angle, the combustion of the oil is effectively ensured by the atomizing air; there is therefore no danger in keeping the oil in one or several

tuyeres which are hardly able to take more hot blast. Carbon black—It is essential, to avoid the formation of carbon black, to be able to diminish, not stop, the flow of oil in the tuyeres when the hot-blast volume is itself appreciably reduced. This is when there is checking and when the wind is cut back while tapping the iron or slag, i.e. the technique of cutting the blast to allow the burden to descend in the furnace, is taking place.

There must be a rapid and foolproof method of reducing, without extra personnel, the oil to all the tuyeres and of re-establishing normal flow once the furnace is back to normal operation.

In the case where an automatic *cut-off* in oil supply is provided whenever the blast volume falls below a certain value, it is also necessary to provide for automatic purging of the injector with compressed air or steam. This gives additional protection against radiation at the nose and prevents oil which has not been expelled by the air or steam from coking; it also avoids the necessity of cleaning the injectors before putting in the oil again. It entails:

an automatic cut-off in the supply

automatic purging of the injector with steam 3 co-axial pipes with automatic admission of protection air between the second and third.

Tuyere obstruction

If there is complete obstruction of a tuyere and the oil is not cut off automatically, it flows into the blowpipe and then onto the floor through the joints between the tuyere and the blowpipe. A keeper then has merely to close the appropriate valve to this tuyere. After a few minutes the tuyere is cleared by the hot blast and the fuel oil can be put in again.

Blockage

The oil must be well-distributed around the whole periphery of the furnace. It is important therefore to inject it into all the normal tuyeres or, for small flows, into every other tuyere. It is also clearly necessary, at a given time, that the flow is the same to each injector. The oil must be carefully filtered both before the pumps and at the inlet to each injector. It is inevitable however, that now and then some injectors are more or less blocked. It is therefore necessary:

to have a warning system for indicating if an injector is blocked

to be able rapidly to unblock the injector without stopping the furnace

to be able to maintain the flow of oil in case of partial obstruction of an injector.

The last two points especially will be discussed.

Cleaning blocked injectors

Blocked injectors may be cleaned and replaced in a few minutes without stopping the furnace. On this subject, the types of injector can be divided into two categories.

Single-piece injectors The whole of the injector must be withdrawn from the tuyeres. This involves opening a circular hole about 35 mm dia. in the bend where the hot blast is fed to the tuyere. In other words, when the injector is removed, hot blast (at  $900^{\circ}$  or  $1000^{\circ}$ C) blows through this hole, which makes the operation hazardous. This is only practicable for blast pressures well below 1 atm.

Injectors in two parts The inside oil pipe can be taken out, while leaving the outer casing in place in the tuyere.

Only a small diameter orifice is then opened and it is the *cold* compressed air for atomizing which comes out of the opening. This system must be used where the hot-blast pressure exceeds 1 atm.

#### Minor obstructions

Short of complete obstruction, it is possible to have, now and again, deposits partially obstructing the filter of an injector or to have slight coking of the oil at the extremity of the injector. It must be possible, in this case, to maintain the normal flow of the oil in the pipe, otherwise the pipes would have to be withdrawn and cleaned each time obstruction started.

For this, a supply system must be provided which maintains the flow, whatever the pressure drop may be. The volumetric pump system is clearly indicated. This permits additionally the establishment of a warning system which shows that an injector is becoming blocked. This warning system is initiated by a pressure P1 in the main. It is also clearly essential to provide a discharge valve for each volumetric pump which

operates as soon as a fixed pressure P2 > P1 is reached in the pipes connecting the pump to the injector. There are as many pumps as injectors and all the pumps are controlled by the same shaft so that they all rotate at the same speed.

It is then easy, by means of a remote-controlled speed regulator, to reduce or increase the oil flow simultaneously to all the injectors, by pressing a button. An even flow is then maintained. Their flow can be measured by a tachometer showing the speed of rotation of the pumps.

Blast distribution

There is then the same oil flow in each tuyere at any given time. Is it necessary to have the same wind rate, in other words, must the blast be evenly distributed?

The author knows of a blast-furnace consuming 2 tons of oil/h, which is rather high, without even wind distribution and which does not cause difficulty from the point of view of the linings. The even distribution of the blast does not therefore seem necessary, but is obviously desirable.

Intermediate oil tanks

If the tanks are situated near the blast-furnaces or are part of the blast-furnace services, an intermediate tank is not necessary. Otherwise a tank to give 4 or 5 h independent operation is advisable.

Emergency use of light fuel oil

Where there is a prolonged stoppage of injection of heavy fuel oil, it is advisable to purge the system of its heavy fuel oil by passing in light fuel oil for some minutes. The steam is shut off and it will also be possible to start up the installation again, when desired, by stopping the light oil and passing heavy oil after reheating the circuit by means of the accompanying steam main.

Purging

Automatic purging of the injectors with steam is used in the event of oil loss (electricity failure, for example). Automatic replacement of compressed air by steam is used if the compressor breaks down.

#### Pompey no.4 furnace

The installation given as an example satisfies the requirements outlined above: distribution with volumetric pumps, two element injectors, and intermediate tank (Fig.2, showing injection installation on Pompey no.4 furnace). The following points should be noted:

the warning system for blocked injector (PIA 10–21)

the by-pass valves (STD5-16)

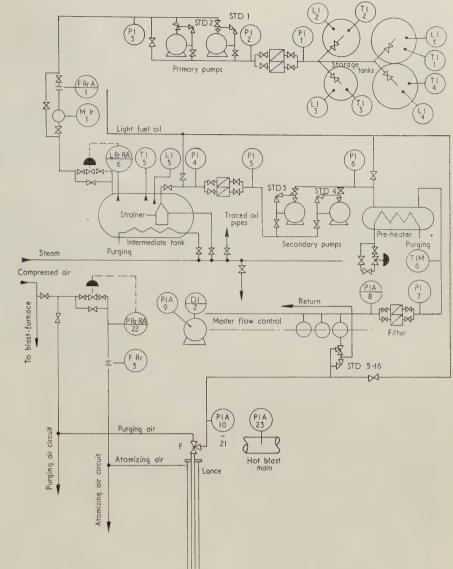
PIA 8 and PIA 9 which inform the operator when the supply to the pumps falls or stops altogether the regulation of the compressed air pressure

(PRrRA-22) and flow (FRr3)

alarm signal PIA 23 which operates if the furnace unexpectedly breaks down to draw attention to the need to stop the oil supply

intake of light fuel oil.

Having regard to the alarm system and to the necessity of acting in an emergency, it is considered an additional complication to install an automatic device to cut off the oil and to purge the system, should there be a considerable drop in the wind rate.



- O Local instrumentation
- O Control panel instrumenta-
- Ir Integrator
- M Meter or recorder

---- Traced oil pipes

- A Alarm
- L Level
- I Indicator
- R Regulator
- Rr Recorder
- T Temperature
- P Pressure gauge
- F Flow meter
- 2 Commercial blast-furnace operation with oil

#### CHOICE OF OIL

The different commercial fuel oils at present available are very suitable. In particular, the high-sulphur oils (up to 3%) are no trouble since, on the one hand, 1 kg of oil replaces 1.7 to 2.4 kg of coke containing 1% sulphur, and on the other, sulphur partition between slag and metal is clearly improved by the injection of oil.

The choice should therefore be made on considerations of supply and cost.

If the works already use heavy fuel oil for other purposes near to the blast-furnaces, storage considerations may be the deciding factor: it can be economic not to create special storage facilities and to make use of the oil consumed in nearby departments (i.e. 0.8%S oil). The choice of one quality may likewise favour large-scale transportation, i.e. complete train loads

As far as the viscosity is concerned, especially in the choice between light and heavy oil, the price differential should always be sufficient to compensate for the differences in heating costs. The cost of steam can vary

in France, between 14 and 35 NF per ton according to the plant.

The specific consumptions of steam are also very variable: from 500 to 1500 kg/t of no.2 oil (for unloading, maintaining temperature in the primary storage tanks, in the intermediate tanks, and traced pipework).

It is advisable, lastly, not to ignore the calorific value in comparing different oils (especially the oils with different S contents).

#### RESULTS OBTAINED BY THE INJECTION OF FUEL OIL

#### Light oil

The report published in August 1960 by ECSC\* entitled 'Essais d'injection de fuel liquide léger dans le H.F. No.3 de Pompey marchant en minerai toutvenant' (Injection trials with light fuel oil on the no.3 blast-furnace at Pompey, operating on run-of-mine

<sup>\*</sup> Translation: Iron Coal Trades Rev., 1961, 182, 1163-1170.

TABLE I

Period Date	Reference 5–25 Dec.		8 months
% fuel-oil, kg/t Fe	0	53	49.2
Normal daily production, t/d Production, per working h, t/h	$258 \cdot 20 \\ 10 \cdot 76$	$\substack{281\cdot5\\11\cdot73}$	$283 \cdot 4 \\ 11 \cdot 81$
Burden, kg/t Fe, %		2 = 20	2 = 2
Droitaument	2693	2583	2582
Giraumont	***		24
Saizerais	494	669	525
Kiruna	80	49	89.3
Mourières	***	• • •	8.7
Jarny	770	119	$31 \cdot 2 \\ 149 \cdot 9$
Scrap, etc.	119	119	149.9
Pebbles Screened coke	1007.9	905.9	908
	29.53	29.35	29.22
Iron content of burden, raw, %. Primary flue dust, kg/t Fe	201.7	183.7	263
Iron content of burden	201-7	100.1	200
(corrected for flue dust), %	32.43	31.93	33.03
Iron analysis, %			
Si	0.60	0.6	0.58
8	0.059	0.031	0.047
C	3.53	3.52	$3 \cdot 49$
Slag	1.44	1.44	1.45
Lime/silica ratio	1.36	1.35	1.49
3, 70 (S)/S	23.05	43.55	1.09
Blast temperature, °C	781 .	868	909
Top gas temperature, °C	111	112	103
10 1	111	112	100
Top gas analysis, %	10.75	19.14	19.64
CO <sub>2</sub>	$\frac{12.75}{26.73}$	13.14	13.64
00	$\frac{26.73}{3.74}$	$\begin{array}{c} 27 \cdot 16 \\ 4 \cdot 57 \end{array}$	$27.64 \\ 5.03$
$egin{array}{c} H_2 \ CH_4 \end{array}$	3.14	0.12	9.03
$CO_2/CO$	0.477	0.12	0.493
Net calorific value, kcal/Nm <sup>3</sup>	916	961	957

ore) and also published in Circ. Inf. Tech. No.4 (1961), already gives most of the information of interest.

The results, given in Table I, of 8 months operation in 1960 confirm these figures.

The improvement in iron quality is further confirmed by Fig.3 which shows the effect of injecting 45 kg of light fuel oil, containing 0.8%S.

It can be seen that the same quality pig iron (0.06%) is obtained, when oil is used, with a slag

having a basicity of 1.4, as is obtained with a basicity of 1.48 without oil: this is for an average Si content of 0.5%. The small spread of the points should also be noted showing the regularity of the iron quality. The points correspond to monthly averages.

#### Heavy oil

The injection of 55 kg of heavy oil per ton of iron in no.4 furnace has led to a reduction of 135 kg (or 13%) in the coke rate and to an increase in output of 15%. The operation of the furnace is perfectly smooth with an average blast temperature of 960°C.

#### Results elsewhere

Usinor-Louvroil 17% reduction in coke rate and the same increase in output with 60 kg of light oil per ton of iron (screened ore burden).

Cornigliano 15% reduction in coke rate (from 685 to 590 kg/ton) and 10% increase in output for 40 kg of heavy oil and blast at 920° (burden consisting of rich ore (58% Fe) and 50% sinter). High driving rate.

It is apparent that the results are valid whether the burden is low-grade or high-grade, prepared or not.

#### INSTRUCTIONS FOR OPERATION AND SAFETY

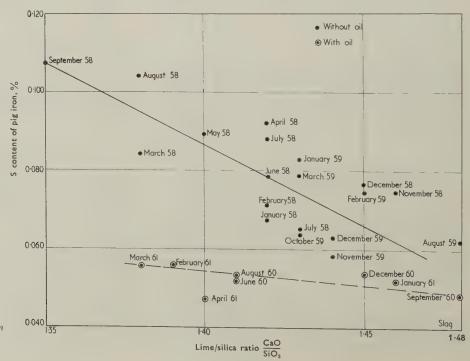
#### Near the blast-furnace

Cleaning an injector

Imagine that the blast-furnace foreman has just been warned by the operator that an injector is blocked. While examining the pressure indicators, he marks the blocked injector.

He must then remove the injector, which can be done in less than 30 s.

The injector is cleaned, the oil is turned on to see if it is properly cleaned; the oil is shut off again and the injector rapidly introduced into the tuyere. The oil is put on and a check is made, from the oil pressure indicator, that the injector is completely unblocked.



3 Ratio basicity v. %S and Si on Pompey blust-furnace no.3 Stopping the furnace

Two hours before cutting the wind, purge the injectors with compressed air or steam, then remove them. The outer casings remain in place, cooled with the compressed air used for atomizing the oil. The purpose of this is to avoid serious burning at the tuyeres when the wind is cut.

Once the furnace is stopped, the outer casings are removed so that the tuveres can be blocked up (bustlemain temperature). The operations are reversed when

These operations are obviously impossible if the injector and outer easing assembly consist of a single

unit.

#### For the operator

Checking and slowing down the furnace

Before checking the furnace, the flow of oil is reduced to 40% of its normal value (e.g. if the pumps rotate at 1100 rev/min, they are slowed down to 500 rev/min). Same operation immediately tapping starts. Oilsupply back to normal as soon as tapping has finished.

Hanging in the blast-furnace

With oil, there is practically no hanging in the furnace. With hot hanging, however (sudden improvement in the quality of the burden), the oil flow is increased from 10 to 15%. Generally in less than an hour, burden descent becomes normal and the oil flow may be returned to its normal rate.

#### **General** instructions

Cutting off the oil

The intermediate reservoir gives 5 h operation, which is more than adequate for putting in a second pump if the first pump breaks down; hence the oil is practically always cut off intentionally, e.g. when there is too much iron or one wishes to reduce output. In this case

it is sufficient to revert to the normal burden at the same time as the oil is cut off. It should be observed that the furnace will continue to operate at the maximum blast temperature without difficulty for several days after the oil has been cut off. The iron quality does not change from the time the oil is cut off until the normal charge arrives at the tuveres.

If the oil is cut off for a few hours, no change in the burden is made.

Regulation of the oil distribution system when oil injection is off for a few hours

Every other Sunday, the furnace is off for about 8 h for maintenance. The work carried out around the furnace is as described under 'Cleaning an injector'.

As far as the volumetric pumps are concerned, they are not stopped but simply slowed down to 500 rev/ min if the stoppage does not exceed 2 h. The pumps then work in closed circuit while the oil injection is off. It is only necessary to watch the steam rate in order that the oil does not become over-heated (temp.  $\leq 90^{\circ}$ C).

If the stoppage is for more than 2 h but less than a day, the pumps are stopped and the steam cut.

It is sufficient to put the steam on again 1 or 2 h before restarting.

#### CONCLUSION

The technique of oil injection into a blast-furnace has now been established.

Certain precautions must be taken to ensure a good distribution of the oil and the minimum of maintenance.

It is advisable to avoid complicating the installation unnecessarily.

There is now no doubt that, providing the stoves are adequate, output can be increased by from 10 to 20% in any furnace and the iron cost reduced significantly by the injection of oil.

Correspondence on the paper

## An electron microscopical investigation of the tempering of 18-4-1 high-speed steel\*

Monsieur A. H. Michel (Chamber Syndicale des Producteurs d'Aciers Fins et Spéciaux, Paris) wrote: The authors show that during tempering for 5 h at 300°C, the carbide M23C6 is precipitated out of the residual austenite. Tempering for 5 h at 400°C produces precipitates in considerable quantity, but no secondary hardening results. It seems to me that one may conclude from this in particular that the change in composition of the residual austenite has not produced any secondary hardening during cooling, because such a transformation would have increased the hardness. The precipitation of  $M_{23}C_6$ , however, impoverishes the austenite in carbon and consequently ought to increase the Ms temperature of resumption of its transformation above the ambient temperature, that is to say,

produce secondary hardening. If this is not produced, it means that a different phenomenon prevents this transformation of the residual austenite, and that is the stabilization of the latter by tempering at temperatures which are not very high.

In short, if tempering did not modify in any way the residual austenite, the resumption of the transformation of the latter during cooling would be effected from the ambient temperature. When tempering impoverishes the austenite in carbon, the resumption of the transformation during cooling ought to take place above the ambient temperature, as appears clearly for tempering at higher temperatures. On the other hand, however, tempering at temperatures which are not very high stabilizes this austenite of modified composition, such that the M<sub>s</sub> is situated at the ambient temperature if there is absolute compensation of the two effects, or below the ambient temperature. By tempering, the residual austenite undergoes two

<sup>\*</sup> C. H. WHITE and R. W. K. HONEYCOMBE: JISI, 1961, 197, Jan., 21-28.

kinds of modification: an impoverishment in C and in alloying elements, and at the same time a stabilization.

Mention ought to be made, however, of the following experimental results: In the course of a dilatometric study on the tempering of high-speed steel using a differential dilatometer, J. Papier and I found that the  $M_s$  temperature on quenching 18-4-1 steel after tempering  $2\frac{1}{2}$  h at  $565^{\circ}$ C was the same as that of the initial as-quenched state, or quenched and tempered at  $400^{\circ}$ C for periods of 2 h, 24 h, and 7 d. These observations show that within the limits of error of the dilatometric test, holding for 7 d at  $400^{\circ}$ C has not appreciably modified the state of the austenite.

I should be glad to have the authors' views on these remarks and experimental results.

Dr J. M. Arrowsmith (Colvilles Ltd) wrote: The authors are to be congratulated for clearly showing that the maintenance of hardness on tempering quenched 18-4-1 steel is associated with a precipitation process in the martensitic regions only. However, I must point out the dangers of making positive identification of precipitates when using an instrument which forms an electron diffraction pattern from an area of the specimen, far larger than that shown in the micrographs. In 18-4-1 steel there are three different regions containing precipitates, the martensite, the retained austenite, and the grain boundaries. Thus there is need for caution in identification.

The authors state that Fig.9 (corresponding to the martensitic regions at  $550^{\circ}$ C) closely resembles the pattern in Fig.6b of the paper (corresponding to a region containing retained austenite). In fact these patterns are totally different. A quick measurement of the radii of the rings of Fig.9 show that they increase in the ratio of the square roots of 3, 4, 8, and 11. This is typical of a simple face centred cubic structure. A rough calibration can be made from the position of the diffuse carbon rings, with the result that the pattern appears to correspond to that of vanadium carbide. The radii of the rings of Fig.6b, on the other hand, increase in the ratio of the square roots of 12, 16, 24, 40, and 48. This is typical of a complex cubic structure and rough calibration shows it to be  $M_{23}C_6$ .

Likewise, Fig.13 (corresponding to the microstructure of Fig.12 at 700°C) is a pattern of vanadium carbide, identical to Fig.9, except having spotty instead of diffuse rings. The thickness of the black particles in Fig.12 is too great for electron diffraction. They are clearly the  $M_{23}\mathrm{C}_6$  which the authors detected by careful low angle X-ray diffraction of extracts. No vanadium carbide would be found by X-ray diffraction as the particle size and the volume fraction in the extracts are so small.

Thus I consider that the evidence presented points to secondary hardening by precipitation of  $\rm V_4C_3$  in the decomposed martensitic regions at  $500^{\circ}\rm C$ . This is exactly the same mechanism as was shown by Smith and Nutting³ to be responsible for the secondary hardening of low alloy vanadium martensitic steels, which reach maximum hardness after 5 h at  $600^{\circ}\rm C$ .

Mr White and Professor Honeycombe wrote: In reply to Monsieur Michel, secondary hardening has in the past been attributed mainly to the formation of martensite from the residual austenite on cooling from the tempering temperature. We believe this to be of only very minor importance, the precipitation of carbides from the martensitic matrix producing the hardening mechanism.

This is usefully illustrated in Fig.4 in the paper (the Q  $160^{\circ}\mathrm{C}$  T  $500^{\circ}\mathrm{C}$  curve). At  $160^{\circ}\mathrm{C}$  only 40% of the austenite has transformed to martensite. Therefore, after tempering, if formation of martensite from the 60% residual austenite were the important factor, the secondary hardening would be large, whereas in fact it is quite small. On the other hand, this latter result would clearly be expected if precipitation of carbides occurred in only 40% martensite instead of in the normal 80%.

The formation of precipitate in the retained austenite, which occurs before the onset of secondary hardening, would reduce the carbon and alloy content of the austenite but only

TABLE 1 Measurements on electron diffraction patterns from extraction replicas

d values	Plane	Lattice parameter		
3.05	(222)	10.58		
2.64	(400)	10.58		
2.51	***	***		
2.18	(422)	10.69		
2.06	(333)	10.69		
1.93	***	•••		
1.77	(600)	10.63		
1.67	(620)	10.58		
1.53	(444)	10.60		
1.38	(533)	10.60		
1.32	(800)	10.53		
1.28	(820)	10.54		
1.25	(822) (660)	10.61		

within the immediate vicinity of the precipitate, as diffusion is very slow at these lower temperatures. Further, the volume contraction which accompanies the first stage of tempering of martensite would relax the elastic stresses around the martensite plates, thus removing the favoured sites for nucleation of further martensite. This would then necessitate a decrease in temperature in order to raise the free energy difference between the two phases to a value sufficient for transformation to take place in less favoured regions. Thus this mechanism of stabilization and the raising of the Ms due to carbon impoverishment would possibly compensate one another. However, the formation of the first martensite plates will result in plastic deformation of the austenitic matrix and some dislocations will be moved away from their anchoring precipitates.2 As long as rapid cooling is continued these released dislocations will remain free, but cooling from the tempering temperature is slow (normally air cooling) and thus the dislocations will become anchored again and martensite formation ceases.

Regarding the effect of holding time at 400°C we would not expect the austenite to have been modified much more after 7 d than after 1 h, the reason being that, as mentioned above, the precipitate forms quickly at first but subsequent growth is negligible and therefore diffusion of alloying elements in the austenite must be extremely difficult. It is only when temperatures in excess of 600°C are attained that diffusion becomes at all rapid.

While we are in agreement with Dr Arrowsmith on the dangers of making positive identification of precipitates from electron diffraction photographs, we would point out that it is equally hazardous to interpret diffraction patterns as reproduced in a journal, and in particular to offer an alternative precise identification of a pattern.

We cannot agree that the diffraction patterns in our Figs.9 and 13 correspond to  $V_4C_3$ . A number of other patterns, the details of which would have been even more difficult to reproduce, have been measured to determine the d values, and from these the lattice parameter of the precipitate. The table includes values determined from rings on several photographs, many of which are not visible on Fig.9 (see Table 1).

The average lattice parameter for  $M_{23}C_6$  is  $10\cdot63$ , with which the values in the table are in fairly good agreement. Moreover, the reflecting planes are consistent to the extent that if a (222) plane gives a reflection, then we would also expect one from (333) and (444). Two unidentified reflections are listed (d values  $2\cdot51$  and  $1\cdot93$ ); positive identification is impossible but WC provides the nearest fit.

The listed values could not be associated with  $V_4C_3$ , patterns which we had previously obtained from boundary regions in replicas from as-quenched specimens.

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# Blast-furnace performance with injection at the tuyeres

J. M. Ridgion

MANY ATTEMPTS have been made to calculate furnace fuel rates or at least changes therein arising from a change in operating conditions. In such calculations it is generally tacitly assumed that true counter current conditions prevail and that across any horizontal plane in the furnace gas and solid temperatures, composition, and flow rates are the same at all points. Fortunately, the increasing elaboration of burden preparation seems to be bringing real furnaces closer to this ideal.

The following factors need to be taken into account in coke rate calculations:

- (i) A mass balance for all materials must be established.
- (ii) An overall heat balance must show that the total heat input is sufficient to cover heat requirements and losses.
- (iii) Note must be taken of the effective temperature in the combustion zone of which a convenient measure is the adiabatic flame temperature. This can be obtained from a knowledge of the proportions and temperatures of all materials entering the hearth including injectants. The economies brought about by increased blast temperature show that a high flame temperature is desirable, but beyond certain limits increased blast temperature or oxygen content can lead to irregular furnace operation due perhaps to displacement of temperature levels low down in the bosh or to formation of silicon monoxide. The permitted flame temperature should therefore be specified in a coke rate calculation to ensure that the results correspond to practicable conditions.

(iv) To maintain a furnace in continuous operation it is not sufficient to ensure a balance between total heat input and the sum of the heat requirements of the process. Each component of the heat needed to sustain chemical reaction is required at a specific temperature and the ascending gases must be able to supply this heat at a temperature at least as high as this. Calculations should therefore be made to ensure that the appropriate heat quantities are available at a sufficiently high temperature. The technique of the heat balance by stages is appropriate.

(v) Although many reactions in the blast-furnace

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The author is deputy head of the Ironmaking Division of BISRA and head of the division's North East Coast Laboratory, near Middlesbrough.

#### SYNOPSIS

The problem of calculation of blast-furnace fuel requirements is examined with particular reference to the effects of injecting fuels and other materials at the tuyeres and varying blast composition and temperature. An examination is made of the thermal and chemical factors which need to be taken into account and earlier work is surveyed in the light of this. The BISRA approach is described and a selection of results of computations is given. 2014

are fixed and invariable, e.g. phosphorus is reduced by carbon and enters the metal, considerable variations may occur in the process of reduction of iron oxide. The proportions of reduction effected by carbon monoxide, hydrogen, and solid carbon have an important influence on the heat requirements of the process, on the efficiency of carbon utilization, and on the composition of the top gas from the furnace. Specification of the extent to which these various reactions occur in a hypothetical practice is a problem of importance and great difficulty. The problem is equivalent to specifying the top gas analysis or the proportion of carbon burnt at the tuyeres.

(vi) Analysis of a furnace practice, existing or hypothetical, is incomplete without some consideration of productivity or driving rate. This is in part a function of coke rate which in turn is affected by productivity, if only through its effect on heat losses.

#### **PREVIOUS WORK**

Although few workers have made extensive use of the heat balance in stages, several have investigated overall thermal balances in detail, some with the aid of electronic computers.

A series of papers has appeared from the research laboratories of the Jones and Laughlin Steel Corporation. These are primarily based on an overall heat balance for the furnace. In general a known base practice is employed and a materials balance established, adjustments being made to burden weights to secure an iron balance and to the blast volume in order to obtain an oxygen balance. A fixed value is taken for  $\rm H_2/H_2O$  in the top gas and the observed  $\rm CO/CO_2$  value is employed.

An overall heat balance is established and gives a value for heat loss which in subsequent calculations is taken as constant per unit time.

In order to calculate the effect of changes in operating conditions on performance, equations are set up to ensure carbon, oxygen, and thermal balances using

the heat loss value previously established. This procedure must be based on assumptions as to the CO/CO<sub>2</sub> and  $\rm H_2/H_2O$  ratios in the top gas: moreover it takes no direct account of the adiabatic flame temperature under the operating conditions to be evaluated. These points are appreciated by the authors who say³: 'The thermochemical model cannot predict what change in blast temperature and wind rate is compatible with smooth operation of the furnace if a major burden change is made, nor can it predict what the new CO/CO<sub>2</sub> ratio in the top gas will be.'

These changes are to be inserted into the equations on the basis of practical experience derived from furnace trials. The authors appreciate the importance of the adiabatic flame temperature, but do not commit themselves to maintaining a constant value, preferring rather to consider similar existing practical experience when choosing a figure for the prediction equations.

A fixed top temperature of 400°F before evaporation of burden free moisture is assumed, but no account is taken of gas/solid temperature differences in the shaft.

The same group<sup>6</sup> has examined heat balances in stages and analysed the factors involved in heat transfer, but these results do not appear to have been incorporated in the thermochemical model.

It seems possible, therefore, that the model may produce solutions which do not satisfy the second law of thermodynamics, particularly for cases involving a

wide departure from conventional practice.

For less extreme changes the mathematical model has successfully accounted for changes in productivity and fuel consumption provided that the appropriate values for top gas CO/CO<sub>2</sub> have been employed. In attempts to evaluate the effect of natural gas additions it is equally necessary to specify the H<sub>2</sub>/H<sub>2</sub>O ratio.

Hodge<sup>7-9</sup> divides the furnace into three zones with boundaries corresponding to solid temperatures of 120° and 1200°C. The central zone, in which 75% of the direct reduction of iron oxide is assumed to take place, is treated as a counter flow heat-exchanger with a coefficient of heat transfer dependent on gas velocity. A known base practice is used to determine this coefficient and the new practice, with injection for example, is adjusted by trial and error to satisfy the heat transfer equation and the thermal balance for this section. This procedure appears to be equivalent to a heat balance by stages calculation for the range 120–1200°C, assuming a linear distribution of heat requirements. There is no direct control of flame temperature in the calculations.

The proportion of iron oxide reduced by carbon is expressed as an empirical function of solids retention time. Hydrogen utilization is taken as 40% in all

normal cases.

Cordier in his paper<sup>10</sup> on injection has given an account of the application of thermal balance calculations to forecasting furnace performance in this field. His method is basically that of the overall heat balance associated with the maintenance of a fixed value of the adiabatic flame temperature. The importance of the proportion of indirection reduction and of hydrogen utilization are brought out and it is made clear that they cannot be calculated in any formal way but must be chosen from practical experience.

'The new top temperature, indirect reduction coefficient, and heat losses are guessed from the anticipated working conditions of the furnace, past experiences with injections, and the analysis of the combustion gases in  $H_2$  and  $(CO+H_2)$ .

No reference is made to the temperature levels at which heat is to be available, apart from the flame temperature criterion which is employed rather as an index to ensure hearth conditions which will favour

smooth driving.

Poos and Decker<sup>11</sup> take the overall heat balance and express it in terms of direct and indirect reduction ratios. For this purpose they consider the whole of the oxygen removed in liberating the metals and metalloids together with that from water decomposed in the furnace. They then determine the fractions of this oxygen which are taken up by carbon, carbon monoxide, and hydrogen.

Their correlations of hydrogen and carbon monoxide utilization with varying conditions of fuel injection using data from the international low-shaft furnace are of considerable value but will require to be verified as data accumulate from full-scale blast-furnace trials.

Colclough<sup>12</sup> has examined the influence of ore preparation and sintering with the aid of partial heat balances worked out for four zones bounded by the temperatures 450°, 800°, and 1000°C. His subsequent studies of the effects of injecting steam with increased temperature or oxygen content of the blast are mainly concerned, however, with the energy balance of the hearth zone and a discussion of the probable influences of gas composition on indirect reduction.

Colclough's figures relating to utilization of the reducing power of the gases are admittedly assumptions based on experience. For prepared burdens he allows a top gas  $\rm CO/CO_2$  ratio of 1.5 corresponding to 40% utilization of CO. The same figure of 40% is taken for hydrogen utilization when working with steam in

the blast.

Taylor<sup>13</sup> subdivided his thermal balance calculations into five zones with boundaries corresponding to solid temperatures of 1350°, 1050°, 900°, and 700°C and apportioned the various reactions between these. Direct reduction of iron oxide was assumed to be distributed between the 900–1050°C and 1050–1350°C zones in the ratio one to two. By comparing thermal requirements of the solids in the various zones with the quantities of heat available from the ascending gases he was able to calculate the gas/solid temperature difference at each boundary and to show how this varied with different operating conditions. The effects of an increase in blast temperature accompanied by addition of steam or coke-oven gas were studied and the advantages of the latter pointed out.

In comparing the results of this work with his earlier studies using the overall heat balance, Taylor concluded that the advantages of the step-wise balance were likely to be confined to studies of rich ore practice. It should perhaps be noted that the cases he considered involved burdens containing limestone with the consequence that his critical region was normally centred on the 700°C level: the introduction of prefluxed burdens tends to transfer the critical levels further down the furnace.

Taylor worked out his examples for various proportions of indirect reduction and analysed the resultant effects on top gas analysis and furnace efficiency. No quantitative method was provided for estimating the appropriate levels for a given case.

Schumacher<sup>14</sup> used the diagram for the heat balance in stages as developed by Reichardt<sup>15</sup> to calculate the effects of blast oxygenation. Inevitably, changes in flame temperature were involved. Attention was directed to the existence of a critical pinch point, the heat requirements above which were used to determine fuel requirements, under conditions of higher blast oxygen content.

Raick and Brassert <sup>16</sup> examined the combined effects of injecting reformed natural gas in the bosh and oxygenation at the tuyeres. While appreciating the importance of maintaining an adequate temperature difference for heat transfer they appear to ignore local effects in the combustion zone consequent on blast enrichment. In their coke rate calculations they require to know the top gas CO/CO<sub>2</sub> ratio. As regards productivity they take as a criterion a constant rate of consumption of coke carbon at the tuyeres while recognizing that with heavy injections of gas the volume of gases ascending the stack may become excessive.

In a later work <sup>17</sup> Raick claims to derive complete data on CO/CO<sub>2</sub> ratios from equilibrium data. One of his conclusions is that no practice based on a carbonate-free burden can produce a top gas ratio below 1·5. Lower values than this have since been consistently maintained in a number of instances. In this paper, too, the gas/solid temperature difference throughout the preparation zone (150–1325°C) is taken as constant at 150°C.

Linder<sup>18</sup> considers a series of five zones bounded by the solid temperatures, 350°, 700°, 1000°, 1200°C and assumes corresponding minimum gas temperatures. Heat balances are calculated between each of the above levels and the tuyere zone, and corresponding carbon requirements worked out. The highest of these various solutions gives the actual carbon requirement. The reactions in the furnace, including direct/indirect reduction, carbon deposition, and solution, are taken from special reducibility tests.<sup>19</sup> The laboratory tests have much in common with those of Klemantaski<sup>23</sup> but the variation of reduction conditions with time is arbitrarily fixed.

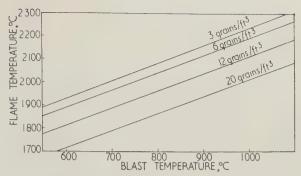
It will be seen that of the many methods put forward, few are concerned with the temperature differences available to bring about transfer of the heat quantities required by the process and that many make no attempt to tackle the problems of direct/indirect reduction in a systematic manner. Despite this, considerable success has been achieved in evaluating the effects of small changes in furnace practice, involving little or no extrapolation beyond current practical experience. For the study of more radical changes in operating conditions it is felt that more rigorous regard will have to be paid to all the factors enumerated at the beginning of this paper. It is for this reason that the present study was undertaken.

#### THE PRESENT APPROACH

The methods developed in BISRA may best be outlined in relation to the factors set out in the introduction.

#### Mass balance

In the majority of calculations carried out on the influence of injecting various materials at the tuyeres an existing practice has been used as a point of



1 Adiabatic flame temperature as a function of blast temperature and humidity

departure. Available data whether derived from special trial periods or from normal works records must be expressed in the form of mass balances. Balances for iron, major slag-forming constituents (CaO+MgO+BaO+Al<sub>2</sub>O<sub>3</sub>+SiO<sub>2</sub>), carbon, hydrogen, oxygen, and nitrogen are considered necessary and sufficient, and the original data must be critically examined and if necessary adjusted to give precise balances for all these constituents.

In many cases, including a considerable proportion of published accounts of blast-furnace trials, the adjustments required are so great that the data are of no practical value. Where the discrepancies are small a variety of methods can be used to arrive at exact balances. A consistent approach can be embodied in a computer program and this has been done by Douglass. His program allows some human intervention based on the judgment of the operator; it greatly facilitates critical examination of operating data and puts the materials in a suitable form for further study.

#### Overall heat balance

This is automatically worked out by the mass balance program. It is also implicit in the more detailed treatment of the section 'Heat balance by stages' below.

#### Flame temperature

The adiabatic flame temperature employed in the calculations is based on the reaction of coke carbon at a temperature of 1500°C\* with the blast and any other injectants entering the tuyeres. In normal blast-furnace practice this temperature is determined by the blast temperature and humidity as shown in Fig.1. It is well known that irregular driving is liable to set in above a blast temperature limit peculiar to the operating practice and that the addition of steam will raise this limit. It seems most probable that the operating limit can be expressed more generally in terms of flame temperature.

As the blast temperature is increased the flame temperature can be kept constant by adding appropriate amounts of liquid, solid, or gaseous fuels as well as steam. High proportional fuel additions will lower the flame temperature with the result that, although more coke may be saved, the replacement ratio of fuel to coke will suffer.

<sup>\*</sup> The precise figure chosen is not of importance: an increase of  $100^{\circ}\mathrm{C}$  would increase the calculated flame temperature by about  $25^{\circ}\mathrm{C}$  but would not change the amount of heat available at any temperature below  $1500^{\circ}\mathrm{C}$ .

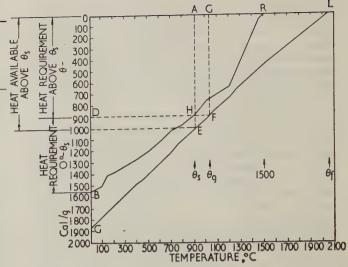
TABLE 1 Annotated examples of results

Separation i	index		
F 7.72477			AE (cf. Fig.2),
<i>DH</i> , °C	DF, °C	AH, cal/g	cal/g
1500	2002	0.0	351.4
1450	1900	71.9	388.9
1400	1738	187.6	427.6
1 350	1617	274.6	$466 \cdot 2$
1 300	1490	358.0	504.8
1250	1379	443.8	559.6
1 200	1268	529.4	597.9
1150	1254	556.5	635.9
1100	1219	583.4	673.5
1050	1185	609.4	711.0
1000	1151	635.2	753.9
950	1085	684.8	799.4
900	1015	737-1	834.3
850	977	779.7	$872 \cdot 5$
800	919	822-2	912.7
750	884	844.5	954.5
700	859	865.3	1009.8
650	797	915.1	1051.1
600	734	$967 \cdot 9$	$1092 \cdot 6$
550	701	1009.0	1134.4
500	659	1043.7	$1175 \cdot 2$
450	618	1077-6	$1227 \cdot 0$
400	579	1110.1	$1264 \cdot 2$
350	547	1136.9	1301.7
300	515	$1162 \cdot 8$	1343.9
250	484	1188.4	1385.9
200	467	1213.1	$1427 \cdot 9$
150	439	1235.9	1470.0
100	360	$1293 \cdot 2$	1512.0
50	333	1316.2	1554.0
	316	$1330 \cdot 4$	1596.0

Practice charact	eristics			
0.71327A	CO	g/g		
0.75938B	CO	010		
0.00220C	$\mathbf{H}_2$			
0.08782D	$\mathbf{H}_{2}^{\mathbf{c}}\mathbf{O}$			
1.6772E	$N_2^2$			
0.00838F	CĤ₄			
$15 \cdot 460G$	CO,	vol.%		
25.865H	CO°	, ,		
1.0505I	$\mathbf{H}_{\circ}$			
$57 \cdot 125J$	$ ext{N}_2^2  ext{CH}_4$			
0.50012K	CH,			
1.6730L	CO/CO,			
0.64691M	Coke "	g/g		
0.54819N	Carbon	0,0		
0.395200	Slag			
0.99986P	Metal			
$2 \cdot 1781U$	Blast air			
0.01715V	Blast H.O	)		
625.00X	Blast tem			

It seems that the highest overall thermal efficiency is attained when the flame temperature is as high as is conducive to smooth furnace operation. In calculating optimum injection effects it is desirable to start with a base practice for a furnace known to be operating near its limit for blast temperature. Subsequent calculations can then be arranged to balance fuel injection against blast temperature and oxygen content in order to maintain the same, supposed optimum, flame temperature. Conditions should then correspond to the minimum attainable replacement ratio, i.e. injected fuel used/coke saved.

To facilitate the calculation of flame temperatures it has been found convenient to specify the characteristics of the injected material in terms of C, H, O, N, Fe, slag, together with a heat function, H, equal to the heat released in bringing the material to the corresponding elementary form. Table II gives examples which include potential injectants other than fuel. The last column indicates the weight of material in 1b/1000 ft<sup>3</sup> of normal blast which will compensate for



2 Typical heat balance by stages

an increased blast temperature of  $100^{\circ}$ C (coke temperature  $1500^{\circ}$ C; flame temperature  $2070^{\circ}$ C).

This column can also be used to obtain interchange ratios; e.g. for each 0.733 lb of steam taken off the furnace it is possible to substitute 1.107 lb of oil without disturbing the flame temperature.

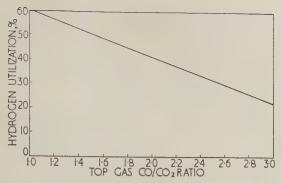
#### Heat balance by stages

Particular attention has been paid to the fact that the heat required by the descending burden must be available to it at a sufficiently high temperature for heat transfer to occur. This has long been realized in principle (e.g. <sup>14,15</sup>) but the technique is not very well known and a short description may be of value.

It is first necessary to consider a number of zones in the furnace each corresponding to a range of temperature of the solid materials and to work out partial or stage-by-stage heat balances. Such a process is susceptible of varying degrees of elaboration from the simplest case of two zones, e.g. above and below 1200°C, to a complete series of steps at 50° or 100° intervals.

A convenient way of illustrating the results of a stage-by-stage balance is shown in Fig.2. Assuming a knowledge of the reactions undergone by various components of the solid change it is possible to determine a burden heat requirement curve (BHR) as a function of temperature, together with a gas line (GL) showing heat available from the ascending gases, again as a function of temperature. Consider the point H corresponding to the solid phase at a temperature DH. In order to complete the processing of this solid a further quantity of heat must be supplied equal to AH and this must be forthcoming at temperatures in excess of DH. In the diagram the gases from the tuyeres can provide the requisite heat (=GF) while cooling to a temperature DF which is greater than DH. If this condition is to be fulfilled at all points between tuyeres and stockline the curves BHR and GL may not cross and indeed must preserve a separation (HF) sufficient to maintain an adequate rate of heat transfer.

In many cases the lines BHR and GL approach each other sharply at one particular point, for example with a burden high in limestone there may be a close approach around 900°C. Where this critical zone, or



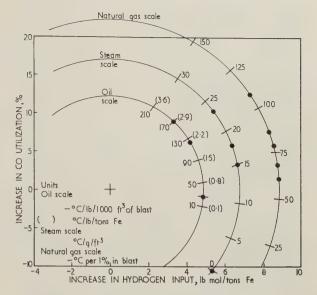
3 Hydrogen utilization (24)

pinch-point, is strongly marked, the corresponding gas—solid temperature difference (HF) can be taken as a criterion of efficiency of heat transfer in the furnace, a small difference corresponding to efficient heat transfer.

In earlier studies in this field it was customary to set up a diagram for a known furnace practice and determine the separation at the pinch-point. The calculation would then be repeated using, for example, a higher blast temperature giving a wider separation at the critical level. The coke rate would then be adjusted by trial and error until the original separation was regained. The final coke rate is then an estimate of what the furnace will do under the new conditions.

In modern practice with self-fluxing burdens no sharp pinch-point may be encountered and some alternative number must be devised to express the separation between the solid and gas curves. For the present work an arbitrary function F (see Appendix) has been developed which is related to the gas—solid temperature differences over the whole range of the diagram. It is a very rough approximation to an overall heat transfer coefficient and can be used for matching up calculated curves in the same way as the simpler pinch-point difference.

The calculations involved in step-wise heat balances are tedious and this may well account for the fact that few workers have employed them, and then mainly with a small number of steps. The computational difficulties become acute when making repeated approximations to determine a coke rate which will give a predetermined value of gas-solid temperature difference. A useful step forward was made by Klemantaski<sup>21</sup> who constructed a multiple slide rule device which considerably reduced the effort required. In order to attain complete mechanization and to permit the study of more complex situations involving fuel



The linear scales are derived from actual results indicated by heavy dots. To use figure: a Calculate effective blast temperature rise per unit of injectant, b draw a line from zero to this point on the appropriate scale, c the point on this corresponding to the increase in  $H_2$  input gives the % increase in CO-utilization

4 Influence on carbon monoxide utilization of injectants containing hydrogen (24)

injection and blast modification a program<sup>22</sup> has been written for the BISRA computer and employed in the work reported below.

The program is normally used to construct a diagram like Fig.2 for a chosen base practice. Table I represents a portion of the results which include values for flame temperature (2002°C) and the function F (7·72). Details are then supplied of proposed changes in blast temperature and composition together with a specification for an injected fuel as set out in Table II. The computer will then determine by successive approximations a quantity of injected fuel and a coke rate which will result in the same values of flame temperature and the function F. Alternative values of flame temperature may be specified or the quantity of injected fuel may be set at a chosen value.

#### **Reduction reactions**

The preceding section includes the phrase 'Assuming a knowledge of the reactions . . .'. The problem here is basically that of deciding what proportions of the oxygen associated with the iron of the charge are removed by reaction with carbon monoxide, hydrogen,

TABLE II Examples of properties of injectants

relea	Heat release	Equivalent		Composition		g/g		lb/1 000 ft <sup>3</sup> blast to
	cal/g, H*	C	. н	0	· N	Fe	Slag	$ m compensate \\ for +100^{\circ}C$
Fuel oil at 150°C Coal rank code 400 Coal rank code 600 Coal rank code 900 Methane Coke-oven gas Steam in blast Magnetite concentrate Limestone	$\begin{array}{r} -483 \\ -184 \\ -344 \\ -409 \\ -1227 \\ -817 \\ -3121 \\ -1004 \\ -139 \end{array}$	0.866 0.775 0.728 0.717 0.75 0.4763 0 0.12	$\begin{array}{c} 0.112 \\ 0.047 \\ 0.047 \\ 0.047 \\ 0.25 \\ 0.2175 \\ 0.1111 \\ 0 \\ 0 \end{array}$	$\begin{matrix} 0 \\ 0.038 \\ 0.067 \\ 0.101 \\ 0 \\ 0.1543 \\ 0.8889 \\ 0.2452 \\ 0.32 \end{matrix}$	0 0·017 0·016 0·014 0 0·152 0	0 0·0161 0·0153 0·0114 0 0 0 0·6417	0.022 $0.15$ $0.16$ $0.15$ $0$ $0$ $0$ $0.1136$ $0.56$	$\begin{array}{c} 1 \cdot 107 \\ 2 \cdot 062 \\ 1 \cdot 866 \\ 1 \cdot 812 \\ 0 \cdot 547 \\ 0 \cdot 708 \\ 0 \cdot 733 \\ 1 \cdot 659 \\ 1 \cdot 487 \end{array}$

<sup>\*</sup> To facilitate subsequent computation H is evaluated using  $C + O_2 = CO_2 + 95\,800$  as for carbon in coke

TABLE III Selected base practice

```
12.94 cwt/ton
Coke rate
                                 10.96 cwt/ton
Carbon rate
                               625°C
7-9 cwt/ton
Blast temp.
Slag volume
                                   0.54 \text{ cwt/ton}
Flue dust
                             6327 tons
Iron make
Blast volume = 40 000 ft<sup>3</sup>/min (STP)
Humidity
                                   4 gr/ft3
Burden
   \begin{array}{lll} \text{Sinter} & 52 \% \\ \text{Foreign ore} & 37 \% \\ \text{Scrap} & 4 \% \\ \text{Fluxes} & 7 \% \end{array}
                                  100%
                                                    26.0
Top gas analysis CO
    by volume, CO_2
   _{\mathrm{CH_{4}}}^{\mathrm{H_{2}}}
                           1.05
                           0.5
                         56.6
   _{\rm CO/CO_2}^{\rm N_2}
 Gross CV Btu/ft<sup>3</sup>
                                                    90.7
 (30in, 60°F, sat)
                                                   210^{\circ}\mathrm{C}
Top gas temperature
Metal, %
                            4.2
    Si
                           0.88
                           0.036
    S
```

and solid carbon respectively. This will apply mainly to the later stages of reduction:

 $\begin{aligned} & \operatorname{FeO} + \operatorname{CO} = \operatorname{Fe} + \operatorname{CO}_2 \\ & \operatorname{FeO} + \operatorname{H}_2 = \operatorname{Fe} + \operatorname{H}_2 \operatorname{O} \\ & \operatorname{FeO} + \operatorname{C} = \operatorname{Fe} + \operatorname{CO} \end{aligned}$ 

These proportions can be ascertained from the materials balance in the case of an existing practice. Moreover, the heat balance by stages computation can be repeated for any desired set of values. The problem remains to forecast the values appropriate to a hypothetical practice for which a computation is to be carried out.

Two ways of attacking this problem suggest themselves.

Various alternative levels of gaseous reduction can be introduced into the computations and full details extracted for the composition of the ascending gases at all levels from tuyeres to stockline. The results can then be examined in light of these data and a personal judgment made as to the most probable combination of gas analyses and reduction data. This is not very satisfactory as different investigators will reach different conclusions depending on their experience and predilections.

A more hopeful approach is to derive systematic relationships between gas analyses and the resultant reactions on the basis of operating data and/or laboratory experiments. The research project 'SCICE'

described by Klemantaski<sup>23</sup> in which burden materials are subjected to reduction in an appropriately controlled gas stream should be of increasing value as results accumulate. Data from full-scale blast-furnace trials involving fuel and steam injection are available in increasing quantity but relatively few include adequate information on gas analysis.

Wild<sup>20</sup> has carried out a survey of available information and deduced the relationships reproduced by his permission as Figs.3 and 4. The latter relates specifically to injection of steam, natural gas, and oil showing the effect of varying degrees of blast temperature compensation on the top gas composition.

The expression 'CO utilization' is defined as  $\mathrm{CO_2/CO+CO_2}$  and Fig.4 shows the percentage increase in this ratio as a function of the increased hydrogen in the system. It is possible that the different degree of temperature compensation correspond to varying adiabatic flame temperatures. As a comparison of Table II with Fig.4 shows, constant flame temperature conditions correspond fairly closely for each fuel with 1% increase in CO utilization for each added 1b mole  $\mathrm{H_2}$  per ton of iron. We may assume that this value applies equally to other fuels, such as coal or coke-oven gas for which direct data are lacking, and use it to make the necessary choice between the alternative solutions put out by the computer.

It is realized that the relationships may need to be revised as more and better documented trials are reported, but even in their present form they constitute a valuable guide and have been employed in the examples quoted below.

#### **Productivity**

Although the main objective of the present work is to analyse fuel requirements, some attention has been paid to the problems of assessment of productivity. For this purpose the hypothesis has been adopted that under injection conditions, the (NTP) volume of gases passing through the bosh, say at a level corresponding to a solid temperature of 1200°C, will be the same as it was in the base practice from which the calculation started. This gas volume may be readily deduced from the computer output. As heat losses of the furnace are proportional to time rather than to output, ¹ changes in productivity will alter the heat loss per unit weight of metal. Facilities are provided in the computer program for changing this value.

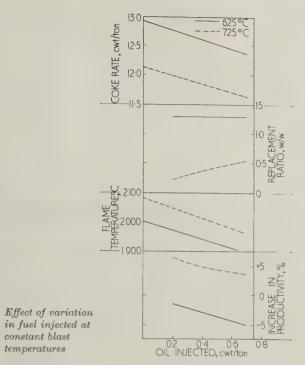
#### **EXAMPLES OF RESULTS**

The variety of results obtained, for different base practices, fuels, and blast compositions, makes it

TABLE IV Effect of various fuels with 100°C increase in blast temperature (21%O2)

	Base	Fuel oil	Coal 601	Anthracite	Steam	Methane	Coke-oven gas
$ \begin{array}{c} \text{Injected fuel (cwt/ton iron)} \\ \text{Coke rate (cwt/ton iron)} \\ \text{Coke saving (cwt/ton iron)} \\ \text{Replacement ratio (w/w)} \\ \text{(Btu/Btu)} \\ \text{Top gas, \%}  \begin{array}{c} \text{CO}_2 \\ \text{CO} \\ \text{H}_2 \\ \text{CO/CO}_2 \\ \text{CV gross (Btu/ft^3)} \\ \text{Potential increase in productivity, \%} \end{array} $	12·94 15·5 25·9 1·0 1·67 90·6	0·57 11·76 1·17 0·49 0·75 16·0 25·1 2·0 1·57 91·0 4·5	0.97 $11.70$ $1.24$ $0.78$ $0.82$ $15.6$ $25.7$ $1.7$ $1.65$ $91.9$ $2.9$	1·37 11·09 1·85 0·74 0·84 15·8 25·6 1·7 1·62 91·1 4·0	a 0·41 12·63 0·31 1·33  16·0 25·7 1·6 1·61 92·1 2·6	$\begin{array}{c} b \\ 0.30 \\ 11.95 \\ 0.98 \\ 0.32 \\ 0.64 \\ 15.9 \\ 25.1 \\ 2.1 \\ 1.57 \\ 91.2 \\ 4.0 \end{array}$	c 0·40 11·91 1·03 0·39 0·61 16·0 24·9 2·3 1·56 91·5

<sup>(</sup>a)  $5.3 \text{ grain/ft}^3$  (b) 1.3% of blast (c) 2.6% of blast



necessary to present a limited selection. It is proposed therefore to examine in some detail a case with one fuel, one practice, involving a simple increase in blast temperature and to summarize data on other fuels and on blast oxygenation.

Table III sets out details of the existing furnace practice chosen, while portions of the annotated com-

puter output are given in Table I.

constant blast

temperatures

A series of computer runs was made with various hydrocarbon fuels and also steam, the results being given in Table IV. A blast temperature increase of 100°C was taken and the fuel addition was automatically varied to maintain constant flame temperature  $(2002^{\circ}\text{C})$  while the coke rate was varied to keep F (7.72) constant. Values of H and I were chosen to accord with Figs.3 and 4.

In practice the flame temperature may not be maintained constant, more or less fuel being injected for a given change in blast temperature. The restriction has been applied in the present calculations for the follow-

ing reasons.

A smaller fuel addition will bring about an increase in flame temperature, the effect being analogous to a rise in blast temperature alone. So long as the blast temperature can be raised without causing irregular driving, this should be done as it is the most effective way of reducing coke consumption. Only when conditions correspond to maximum blast temperature without added fuel or steam should fuel addition be practised, and this should be accompanied by a balanced blast temperature increment to keep the flame temperature up.

Larger fuel additions which bring about a decline in flame temperature are not conducive to maximum fuel efficiency. This point is brought out in Fig.5 which presents the results of a series of calculations using variable amounts of fuel oil always with the same increase of 100°C in blast temperature. With large amounts of oil the replacement ratio suffers, while reduced amounts will lead to instability if the base practice represents the best that can be done without injection.

Maximum thermal efficiency of the furnace does not necessarily correspond to optimum economics and for a specific case it is desirable to carry out calculations for a wide range of conditions. These can then be studied in relation to availability and price of the various fuels, including the blast-furnace gas, and with reference to stove capacity, iron demand, and other factors.

Reverting to calculations based on constant flame temperature and to 100°C blast temperature rise. Table IV suggests that the gaseous fuels considered have a more favourable replacement ratio on the basis of calorific value as well as weight for weight than oil or coal. On a thermal basis the difference between oil and coal is not very great.

As can be anticipated from Table II, the absolute amounts of fuel injected vary considerably; a fixed increase in blast temperature will support the injection of far more anthracite than liquid and gaseous fuels which place a higher thermal demand on the combustion zone.

The last line in Table IV shows the increase in iron make attainable if the volume of gases at the 1200°C level in the bosh is the same as in the base practice.

Table V repeats the calculations on the basis of enrichment of the blast to 25% O2 in place of additional preheat. Comparison of the first lines of Tables IV and V shows that oxygenation to 25% permits the use of about  $2\frac{1}{2}$  times the amount of fuel which can be carried by an increase in blast temperature of 100°C. Replacement ratios in Table V are less advantageous than in Table IV owing in part to the generally higher level of injection. Moreover it will be noticed that the thermal replacement ratio is similar for all fuels though the absolute savings vary over a wide range.

TABLE V Effect of various fuels with blast enrichment to 25 % O2 (no change in blast temperature)

	Base	Fuel oil	Coal 601	Anthracite	Steam	Methane	Coke-oven gas
Injected fuel (cwt/ton iron) Coke rate (cwt/ton iron) Coke saving (cwt/ton iron) Replacement ratio (w/w) (Btu/Btu)  Top gas ,% CO <sub>2</sub> CO H <sub>2</sub> CÖ/CO <sub>2</sub> CV gross (Btu/ft <sup>3</sup> ) Potential increase in productivity, %	12·94 15·5 25·9 1·0 1·67 90·6	1·38 10·61 2·33 0·59 0·90 18·1 26·6 3·5 1·47 100·6 12·8	2·33 10·39 2·55 0·92 0·97 18·0 27·4 2·8 1·52 100·6 12·0	3·29 9·09 3·83 0·86 0·98 17·9 27·5 2·7 1·54 100·2 13·5	$d\\0\cdot 97\\12\cdot 86\\0\cdot 07\\13\cdot 09\\18\cdot 4\\28\cdot 0\\2\cdot 7\\1\cdot 52\\103\cdot 1\\9\cdot 3$	$e\\0.71\\11.21\\1.73\\0.41\\0.81\\18.4\\26.0\\3.9\\1.42\\100.2\\13.1$	$\begin{array}{c}f\\0.94\\11.18\\1.76\\0.53\\0.82\\18.4\\25.9\\4.3\\1.41\\101.3\\14.1\end{array}$

<sup>(</sup>d)  $14.4 \text{ grain/ft}^3$  (e) 3.6% of blast (f) 7.3% of blast

TABLE VI Effect of anthracite with 100°C increase in blast temperature for various furnaces

Furnace	A	В	C	D	<u>E</u>	F
Original coke rate (cwt/ton) Slag volume (cwt/ton) Total burden (cwt/ton) Anthracite injected (cwt/ton) New coke rate (cwt/ton) Coke saving (cwt/ton) Replacement ratio (w/w)	15·40 8·26 38·98 1·58 13·17 2·23 0·71	$16 \cdot 19$ $9 \cdot 42$ $39 \cdot 90$ $1 \cdot 67$ $13 \cdot 76$ $2 \cdot 43$ $0 \cdot 69$	16·50 19·25 51·68 1·76 13·97 2·53 0·70	14·16 9·05 36·64 1·62 11·97 2·19 0·74	$\begin{array}{c} 24 \cdot 16 \\ 21 \cdot 08 \\ 57 \cdot 14 \\ 2 \cdot 79 \\ 20 \cdot 02 \\ 4 \cdot 14 \\ 0 \cdot 67 \end{array}$	$12.94 \\ 7.90 \\ 37.32 \\ 1.37 \\ 11.09 \\ 1.85 \\ 0.74$
Calorific value of top gas (Btu/ft³)  Base Injection case Top gas CO/CO₂: Base Injection case Potential increase in productivity, %	103·2 103·9 2·38 2·30 4·0	$104 \cdot 2$ $104 \cdot 8$ $2 \cdot 79$ $2 \cdot 65$ $4 \cdot 7$	100.7 $101.5$ $2.79$ $2.64$ $5.0$	$85.5 \\ 85.7 \\ 1.63 \\ 1.55 \\ 4.5$	113·1 114·6 2·88 2·74 6·8	90.6 $ 91.1 $ $ 1.67 $ $ 1.62 $ $ 4.0$

All the results presented so far relate to a single chosen base practice, that of Table III. Similar arrays of data could be tabulated for other furnaces but a selection seems more appropriate.

Table VI considers the injection of anthracite with 100°C blast temperature increase for a number of furnaces. Despite the wide disparity in base practices considered, it will be seen that replacement ratios are fairly constant, the coke saving and the level of injection being higher for furnaces with initially high fuel consumptions.

#### CONCLUSIONS

1. An attempt has been made to lay down the conditions which should be satisfied by any method of calculating blast-furnace fuel rates or changes therein resulting from fuel injection or other changes in operating conditions.

These relate to:

- (a) materials balance (conservation of mass)
- (b) overall heat balance (1st law of thermodynamics)
- (c) flame temperature (2nd law of thermodynamics)
- (d) heat balance by stages (2nd law of thermodynamics)
- (e) reduction reactions (chemical kinetics)
- (f) productivity and gas flow (aerodynamics)
- 2. Previous work has been reviewed in the light of the above and certain shortcomings noted.
- 3. A method of calculation, developed for electronic computer, has been described. This takes full account of the above factors with the exception of (e). This latter is allowed for by an empirical relationship based on current available operating data. As further experience is gained with injection and more accurate furnace data, particularly relating to top gas become available the empirical relationship can be made more precise. In the present state of knowledge this approach is more likely to be successful than attempts to apply kinetic data derived from laboratory work.
- 4. Examples of the application of this method to fuel injection studies are given.
- 5. The economics of injection must in all cases depend on local costs of fuels, steam, and hot blast, and on other local conditions, but the methods of calculation outlined would appear to afford a valid criterion for assessment.

In the majority of cases it is advantageous to start from a base practice with the highest blast temperature conducive to smooth driving and to inject fuel with simultaneous corresponding increase in blast temperature. Of the injectants considered, steam appears to be least conducive to improved coke economy and its use in association with hydrocarbon fuels is not desirable if minimum total fuel consumption is the primary aim.

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#### APPENDIX

The separation function, F

For each step of 50° in solid temperature we evaluate

 $\frac{\varDelta H_{\theta}}{\theta_{\rm g} - \theta_{\rm s}}$ 

(=heat transferred/mean gas-solid temperature difference).

The sum of these terms from 0-1500 °C is the function F. Each term may be looked on as

$$\frac{\varDelta H_{\theta}}{\theta_{\rm g} - \theta_{\rm s}} \ = \ h \ k \ A$$

where h is the vertical distance between 50° isotherms, k is a heat-transfer coefficient, and A is the surface area of stack per unit height.

If A and k are roughly constant the component terms of F

give a measure of the variation of solids temperature with height up the furnace.

Ceckler and Lander<sup>6</sup> take k proportional to the fourth root of the absolute temperature and use a term

$$\frac{1}{(\theta_{\rm g}-\theta_{\rm a}) (\theta_{\rm g}+273)^{\frac{1}{4}}}$$

to estimate variations of  $\theta_s$  with furnace height. This implies an assumption that the burden heat requirement curve is a straight line, which is not so.

## Recent developments in burden preparation in French blast-furnaces

J. E. Astier, J. Michard and P. Dancoisne

#### INTRODUCTION

PREVIOUS PAPERS<sup>1, 2</sup> have pointed out that the French iron and steel industry is largely based on the use of low-grade self-fluxing iron ores from the Lorraine deposit, the so-called 'minette' ores. These ores are similar to UK ores, e.g. Northants or Frodingham, and they produce low-grade self-fluxing burden in the blast-furnace with resulting high slag volumes of about 1 to  $1\cdot 2$  ton per ton of iron.

Blast-furnace operation with such ores was possible, even on unprepared burden, with small blast-furnaces. Before the war it was a standard practice, but it must be said that the ore was carefully sized by selective operations in the mines. After the war when iron mines had to produce increased quantities and large-scale mechanized operations became common, this careful selection was no longer possible. Blast-furnace operators, consequently, were simultaneously faced with many big pieces in the ore of more than 8in (200 mm) with more fines, and with a lower iron content, 30% on the average instead of 33% or 35% from the selectively mined ores. Difficulties arose in operating the blast-furnaces and there was a rise in the coke rate from 1 ton of coke per ton of iron increasing to  $1 \cdot 1$  or  $1 \cdot 2$  in some furnaces.

The solution to this difficult problem was found in a careful preparation of the burden, starting with ore crushing, and screening out of the fines which were agglomerated. Later several plants constructed more elaborate plant where the whole ore was crushed to sinter size, and the blast-furnace was operated with  $100\,\%$  self-fluxing sinter. At the same time, ore blending was increasingly used to achieve a uniform burden.

These developments led to spectacular improvements for both coke rate and iron production; Fig.1 gives a general picture of the evolution of coke rates. Table I outlines in greater detail the decrease in average coke rates in French blast-furnaces.

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The authors are at the Institut de Recherches de la Sidérurgie, Station d'Essais, Maizières-les-Metz, France.

#### SYNOPSIS

The paper provides a survey of recent developments in burden preparation in France.

Experimental data of blast-furnace practice with 100% sinter are given and discussed from the point of view of coke rate and iron production.

An attempt is made to give a theoretical interpretation of blast-furnace operation using data obtained from investigations in the shaft. The probes used are described.

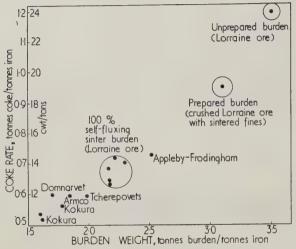
The suggested model of the furnace, operating with 100% self-fluxing sinter can be used for a number of calculations to improve blast-furnace practice. 2010

### EXPERIMENTAL DATA OF BLAST-FURNACE PRACTICE WITH 100% SELF-FLUXING SINTER

Data which were collected are related to experiments where Lorraine iron ores were the only, or at least the most important, part of the sinter mix. These experiments were conducted in Germany at the Saar, Dilling, 3 and Völklingen 4 plants; in Belgium, mainly at the Seraing works of Cockerill Ougrée 5, and also at the International low shaft furnace which has been used, for several years, as an experimental blastfurnace 6; and in France at the Hayange works of De Wendel Company 2 and, more recently, at Mont-Saint-Martin (Lorraine-Escaut Company). 8 Currently further experiments are going on in a number of plants.

It must be stressed that, in almost every experiment, fine and not crushed ore was used in the sinter mix. These fines are obtained by screening at  $\frac{3}{8}$ in (between 6 and 12 mm) with the ore crushed at about 4in (between 60 and 150 mm). Owing to a selective effect of the crushing of iron minerals v, calcite, these fines are richer in iron than the usual mine ore. This effect has two important consequences.

First, the results which were obtained are not representative of what will be achieved when the whole ore is crushed to be sintered as in Appleby-Frodingham



1 Coke rates v. burden rates in various plants

practice. The change in slag volume is rather important, as can be seen in Table II. As has been noted elsewhere, slag volumes could be reduced from, say 1200 kg/t\* of iron (24 cwt/ton of iron) to about 800 kg (16 cwt/ton) by beneficiation of Lorraine iron ores.

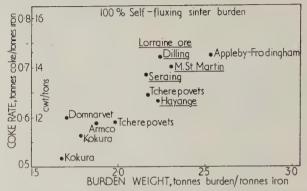
Figure 1 shows what we may hope for in future, and helps to explain the great development in sintering capacity of the French iron and steel industry; the main data in this development are given below:

Sintering capacity of plant built in France, t×106 Nodulizing kilns built between 1957 and 1961 1.8 Pan-type sintering plants built between 1956 and 1960 1.5 3.3Total Continuous sintering plants built before 0.72.0 1.3put into operation in 1958 4.0 $2 \cdot 0$ 1959 1.0 1960 5.02.5 scheduled for 1961 7.51962 6.0 13.5 about 16.0 estimated for 1963 about 2.5 1964 5.021.0 1965 5.026.0

TABLE I Decrease in coke rates in the French iron and steel industry

Year	Coke rate, t/t of iron*	$\begin{array}{c} \text{Iron production} \\ \text{t} \times 10^6 \end{array}$
1929	1.096	10.29
1938	1.046	6.00
1950	1.048	7.76
1951	1.091	8.75
1952	1.085	9.77
1953	1.081	8.67
1954	1.050	8.84
1955	1.069	10.96
1956	1.078	11.48
1957	1.075	11.91
1958	1.065	11.97
1959	1.005	12.46
Estimated for 1965 Best coke rate in experiments with	0.850	20.00
100% sinter	0.633	

<sup>\*</sup> t=metric ton (tonne)



2 Coke rates v. burden rates using 100% self-fluxing sinter

Secondly, the results which have been obtained are in the same range as a number of experiments made in USSR. They lie just between rich sinter practice as in the USA or Japan (see Table I), and low-grade sinter practice as in Appleby-Frodingham.

#### Coke rates

Coke rates are given in Table III and Fig.2. For reference, we have given the coke rates for some high-grade sinter experiments, and recent Appleby-Frodingham practice.

From Fig.2, two important facts are evident. First, the effect of slag volume on coke rate is slight. This is obvious if we compare the quantity of coke which is necessary when, say, 100 kg of extra slag or CO<sub>2</sub> (from limestone) are charged. The amounts are about 20 kg coke for 100 kg slag, and 70 to 80 kg coke for 100 kg CO<sub>2</sub>. This is illustrated by the graphs of Figs.3 and 4 which show the advantages of sintering Lorraine ores.

Secondly, and as a result, if coke rates only are being considered, there is no great difference when using rich self-fluxing sinters, e.g. with 60% Fe, and when using low-grade self-fluxing sinters with only 40 to 45% Fe.

This statement must, however, be modified to some extent. When using low-grade ores the consumption of coke breeze (or any equivalent solid fuel) at the sintering plant is far higher than when using rich ores, and the low-grade self-fluxing sinter leads to more problems when the furnace is being used for high production than occur when rich burden and lower slag volumes are employed.

These are the real keys to beneficiation of iron ores

TABLE II Slag volumes in a number of experiments with  $100\,\%$  sinter burden

Location of experi	Slag vol kg/t of iron	ume, ewt/ton	
Japan: 100% sinte	er experiment at Kokura <sup>10</sup>	440	8-8
USA: $100\%$ self-fl 85% pellets	uxing sinter experiments experiments at ARMCO <sup>11</sup>	270 367	5·4 7·3
Sweden: 100% sel at Domn	f-fluxing sinter experiments arvet <sup>12</sup>	430	8.6
Russia: Tcherepov	rets plant <sup>13, 14</sup>	835 685	16·7 13·7
Experiments with Lorraine ores	Dilling <sup>3</sup> Seraing <sup>5</sup> Hayange <sup>7</sup> Mont-St-Martin <sup>8</sup> Völklingen <sup>4</sup>	892 820 820 802 887	17.84 $16.40$ $16.40$ $16.04$ $17.74$
Appleby-Frodingh	0	1 200	24.00

TABLE III Coke rates for experiments with high sinter burdens

		Coke rates,		
Location		kg/t of iron	ewt/ton	
Japan: Kokura <sup>8</sup>		548	10.96	
USA: 100% sinter	539	10.78		
85% pellets Sweden: 100% Se	591	11.82		
Domnary	$ m et^{10}$	605	12.1	
Russia: Tcherepov	rets	645	12.9	
_		591	11.8	
Experiments with	Dilling <sup>1</sup>	720	14.4	
Lorraine ores	Seraing <sup>3</sup>	687	13.74	
	Hayange <sup>5</sup>	633	12.66	
	Mont-St-Martin <sup>6</sup>	705	14.1	
	Völklingen <sup>2</sup>	694	13.88	
Appleby-Frodingh	am, 1960	725	14.50	

and not, as is very often thought, the influence of iron content of the ore on the coke rate.

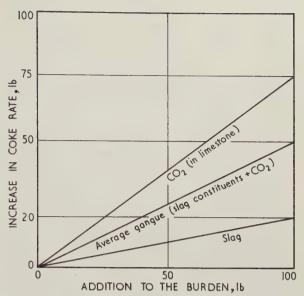
#### Iron production

The use of low-grade self-fluxing sinter in blastfurnaces leads to a large volume of slag and it may be that more problems may be expected when aiming to achieve high production rates than occur with the use of richer sinters or pellets.

Table IV gives actual production from a number of blast-furnaces using low-grade self-fluxing sinters. Until now, all the experiments have been made in rather small blast-furnaces because of insufficient sintering capacity and the lack of big blast-furnaces (e.g. the 28-ft blast-furnaces which are just being put in operation). However, there was a very large increase in production when these blast-furnaces used high sinter burden. Iron production rose to between 150% and, in some cases, 200% of the usual output of the furnace. These production rates are, however, not the largest in the world, as is clear from Table IV where we have given, for comparison, some outstanding performances of Russian and US blast-furnaces.

## THEORETICAL INTERPRETATION OF BLAST-FURNACE OPERATIONS WITH 100% SELF-FLUXING SINTER

Overall data about blast-furnace operations have already been given and from them it is possible to establish overall thermal balances. Some information was available in CESSID lectures on the blast-furnace<sup>15</sup> in papers related to some of the experiments mentioned previously.<sup>7, 8</sup> To progress it was necessary to obtain data on the conditions prevailing inside the blast-furnace, and to establish a theoretical model of the blast-furnace which would be checked against overall results as well as with data collected from probes into the furnace.



3 Schematic representation of increase in coke rate due to different additions to the burden

#### Investigations inside the blast-furnace

Investigations are made with probes. When 100% self-fluxing sinter is used far more interesting results are achieved than when charging a rather complex burden with different ores, stone, and coke. By using probes in a stack with only self-fluxing sinter and coke, it is possible to obtain useful information about conditions prevailing in the furnace stack.

 $Probe\ for\ gas\ sampling,\ pressure,\ and\ temperature\\ measurements$ 

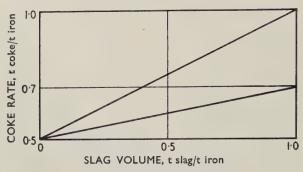
The probe facilitates gas sampling and measurement of pressure.

It is about 16 ft long and 1¼in dia., and is made of welded concentric pipes as shown on Fig.5. The water inlet is made just around the central gas line, for effective tempering of the gas sample. The water inlet and outlet are nipples welded to the 1¼in pipe at a 90° angle. The leading end of the probe is a screwed steel piece in which small holes have been drilled to sample the gas. On the other end there is screwed a machined steel piece with a nipple at a 90° angle; this is the gas outlet and is provided with a gland assembly for the insertion of a thermocouple in the axis of the gas line. The apparatus is protected by a steel casing; it is possible to whack this with a maul or a pneumatic hammer, when it is necessary to insert the probe in the furnace.

Water pressure of about 40 lb/in<sup>2</sup> is sufficient for

TABLE IV Iron production in some blast-furnaces with high sinter burdens from Lorraine ores

	Blast-furnace data Diameter,			Working v	olume,	Iron produ	Iron production,	
Location	m	ft	in	$m^3$	ft <sup>3</sup>	t	tons	t/m³/d
Dilling <sup>1</sup> Seraing <sup>3</sup> Hayange <sup>5</sup> Mont-St-Martin <sup>6</sup> Völklingen <sup>2</sup> ARMCO Tcherepovets Magnitogorsk	5 5 5 5 65 4 8 6 50 8 5 7 6 7 6	16 16 18 15 21 28 25 25	5 5 6 9 4	485 497 621 660 703 1550 1180 1180	17120 17544 21920 23300 24816 54700 41650 41650	511 445 822 690 866 2450 1830 2042	503 438 810 680 859 2415 1802 2011	1·05 0·90 1·32 1·05 1·23 1·58 1·55



4 Diagrammatic representation of the evolution of coke rate with ore and sinter

effective cooling of the probe. The pressure is measured with a quicksilver manometer connected with the gas sampling nipple. Gas samples are taken at intervals of about a foot on the height of the stack. The analyses are made on automatic analysers: for CO and  $\rm CO_2$  they are based on the absorption of an infra-red radiation by the gas, for the hydrogen on conductivity measurement.

For temperature measurements, at the end which is inserted in the furnace, an insulated steel piece must be screwed; about Sin long, with holes drilled in the front of the refractory material, so as to prevent cooling of the gas from the probe. The thermocouple end is situated just behind the holes in the insulated part. We used thermocouples  $\frac{3}{64}$  to  $\frac{9}{64}$ in dia. of the thermocoax type.

#### Equipment of the shaft

A 3in dia. hole is drilled through the stack brick wall at the level of each probe platform. The hole is sheathed with a steel pipe which is fitted through a flange to a 4in dia. pipe welded on to the furnace shaft. On the flange, a 3in bronze valve with a gland assembly is fitted.

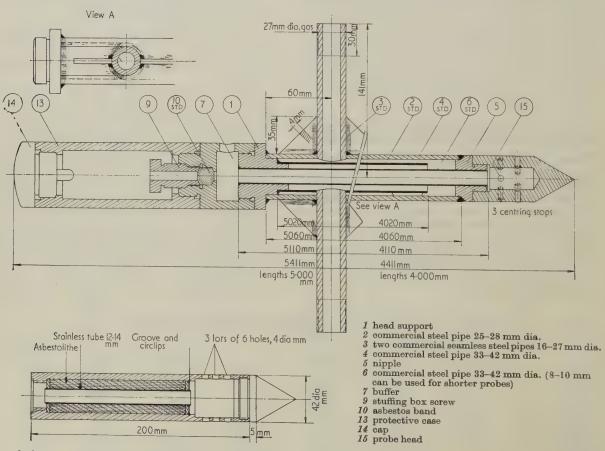
#### Probe for materials sampling

For materials sampling we use a probe which is not cooled. This probe is made of two concentric steel pipes. The outside pipe is provided with apertures. Small buckets machined in the inner pipe may be moved to these apertures. Rotation of the inner pipe closes the apertures.

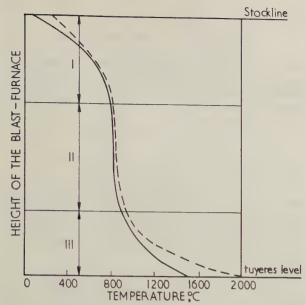
This probe has been successfully used to study the process occurring in the furnace shaft. Several plants now use such probes as a very efficient control tool, and the equipment has been described in some detail.<sup>16</sup>

#### Interpretation of data obtained from probes

From temperature measurements made in the shaft of the furnace (Fig.6) we can see that from the stockline, the temperature increases very sharply. At 12 ft under the stockline level 900°C is reached. In the middle and lower part of the shaft the temperature undergoes very little change due to the height. At the bottom of the shaft, temperature increases sharply again. Measurements have not been made beyond this level, but it is quite reasonable to extend the curve to reach the tuyere temperature. In this way we can get a complete gas temperature graph of the inside of the furnace.



 ${f 5}$  A probe for gas sampling, pressure, and temperature measurements



6 Temperature of solids (unbroken line) and gases (broken line) as a function of the height (from Kitaiev)

With regard to gas composition, which may be equated with the  $\mathrm{CO}_2$  content, a similar evolution is found: at first decreasing from the top gas content, 13% to about 9%, then slowing down in the middle part of the shaft, and again a sharp decrease at the bottom.

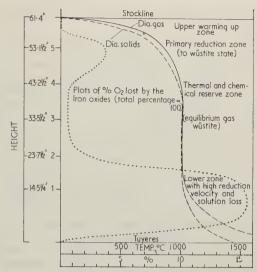
This overall sketch of temperature and gas evolution has been sustained in its main lines by many results we now have. From the thermal point of view, Kitaiev considers that the furnace can be subdivided into three zones: an upper zone where significant heat exchange occurs, a middle part with little heat exchange, and a lower zone where there is again significant heat exchange.

If we consider the general shape of the temperature curve in the shaft (Fig.6), we see that we can consider the first two zones as a counter-current heat exchanger in which the thermal capacity (thermal capacity being the product of mass flow by specific heat) of solid is lower than that of the up-going gas. In contrast the lowest part will be another exchanger in which the heat capacity of gas will be lower than that of the solid stock. According to Kitaiev it is the ratio of these heat capacities along the height which produces the concavity of the temperature curves.

We can note particularly that the difference of temperature between solid and gas decreases at first (going down the shaft) until a defined temperature level has been reached, when, in the lowest part of the furnace, it increases to 1500–1600°C at tuyere level.

It is as if physico-chemical phenomena occurring in the blast-furnace were completely different in kind from a defined temperature level, which we have called 'critical temperature'. An accurate examination of the phenomena, such as thermal calculations, <sup>15</sup> will show the nature of the change more clearly.

Below the critical temperature level (900–1000°C) the only thermal effects taking place in the blast-furnace are those due to the warming up of solid materials and the cooling of gas as they occur in a counter-current process; in fact the iron oxide reduc-



7 Reduction intensity of iron oxides

tion process which occurs in that zone has very little thermal effect and can be ignored.

Throughout that zone the difference between solid and gas temperature is very small (a few degrees perhaps) which explains the very slight temperature evolution occurring along the height. It is as if in a part of the shaft no heat exchange exists and therefore thermal exchange is nearly complete in that zone. In that part of the furnace no reaction of the gasification products of carbon would occur except for the reduction itself, and thus the reaction of carbon deposition will be of very little significance.

In the lower part of the furnace the thermal phenomena are completely unbalanced: in our view, this is due to a very strong endothermic reaction, the gasification of carbon  $CO_2+C\rightarrow 2$  CO.

As soon as this reaction begins, the thermal effect occurs and the temperature difference between solid and gas increases to provide the heat for the reaction. The sinter is rapidly heated, the liquid phase soon begins, and finally complete melting takes place.

If the evolution of the gas analysis is considered, <sup>5–8</sup> it seems that inside the limits of the thermally inactive zone, a chemically inactive one can exist. This zone may be regarded as useless; however, an increase in blowing rate which lowers the heat exchange will decrease this inactive zone<sup>6</sup> so that there may be a critical blowing rate beyond which the heat consumed per ton of pig iron increases.

On this basis we assume that most of the so-called indirect reduction, i.e. reduction by CO not followed by a reaction between CO<sub>2</sub> and C, takes place in an isotherm bed at a temperature level of about 900° to 1000°C, especially suitable for the kinetics of the reduction process. Gasification reaction is essential for the existence of a middle temperature zone, which is necessary for reduction of the iron oxides.

A new aspect of the influence of the reactivity of coke is evident. A coke with too much reactivity will lower the temperature level of the isotherm bed, and may disturb the reduction phenomena. A coke with a low reactivity index may increase the temperature in the isotherm bed such that melting might be the first endothermic reaction to occur. Premature melting

in the shaft may have very adverse effects on furnace

performance.

Reference to the gas composition curves shows that the problem is more complex. Taking into account the oxygen quantity bonded to the iron in the different kinds of oxides, and the reduction equilibria (at least at the working temperature of the shaft) one can see that it is impossible to have a complete indirect reduction, i.e. it is difficult to prevent one part of the CO<sub>2</sub> from reacting with carbon. Coke rates with a sinter burden (nearly always lower than 15 cwt/t of iron) are low enough to develop gasification in the middle temperature zone automatically. Therefore gasification would have, besides its stabilizing effect on temperature, an equally important effect of restoring the reducing power of the gas.

The reduction process may be explained as follows. In the upper part of the shaft the oxides  $\mathrm{Fe_2O_3}$  and  $\mathrm{Fe_3O_4}$  are reduced to wüstite. In the lower part wüstite is reduced to iron. In at least the middle part there is no reduction at all, the wüstite from the upper part being in equilibrium with the rising reducing gas, the  $\mathrm{CO_2}$  content of which comes from the reduction of wüstite to iron. We found in this inactive zone, a ratio  $\mathrm{CO_2/CO_2} + \mathrm{CO}$  equal to 0.25.6,7 Analysis of materials extracted from the shafts at Liège,6 Hayange,7 Mont-Saint-Martin,8 give convincing support to the assumption of a two-phase reduction process.

Figure 7 is a diagram giving, for the Hayange test with 100% sinter burden, 7 the evolution of gas temperature, solid temperature, and reduction intensity along the height of the furnace. The thermally and chemically inactive zone of the furnace is obvious in this diagram.

#### CONCLUSIONS

Experiments made in a number of blast-furnaces using high-sinter burden from Lorraine ores indicate it is possible to achieve:

- (i) an important decrease in coke rate down to, say, 13 cwt/t of hot metal which seems promising if the rather large slag volume, about 17 cwt/t of iron, is considered
- (ii) an increase in production, which is already quite important; further developments in this direction are contemplated especially by the use in larger furnaces of a better screened sinter.

Interpretation of the data given in the first part of our paper, as well as results of investigations by probes inside the stack, given in the second part, suggest a model of the blast-furnace operating 100% self-fluxing sinter burden.

The model of such an ideal blast-furnace can be worked out, taking in account thermal requirements in each zone and the reduction equilibrium described in the stack. Normally we can limit ourselves to the thermal requirements of the lower part of the furnace, where the temperature is above 1000°C. The calculation takes into account:

as input: preheated charge at  $1\,000^{\circ}$ C with iron oxides prereduced to the wüstite level

as output: liquid hot metal and slag; hot gases at 1000°C with the equilibrium  $CO_2/CO+CO_2=0.25$ 

Thermal balance and oxygen balance may make possible calculation of the proportion of carbon burnt at tuyere, the degree of solution loss, and the volume of gases. These values can be used to establish the thermal balance of the upper part of the furnace so as to calculate temperature and composition of blast-furnace gas.

Such a model has already been used for a number of calculations, <sup>15</sup> particularly for another improvement in blast-furnace practice: oil and gas injections in combination with the use of higher blast temperature and

oxygen.

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## Rotary straightening of bars

J. F. Wallace and D. H. Thompson

TO REMOVE the out-of-straightness which develops during forming and heat treatment, the majority of steel bars are rotary straightened. During the 1939-45 war, tensile tests taken along the length of a bar of alloy high-tensile steel showed that the straightening process had induced a substantial reduction in the limit of proportionality, LP, and the 0.1% and 0.25% proof stresses, although the maximum stress and the uniform and total elongations remained unaffected. Further examination revealed that this modification of the stress-strain relationship, Fig.1, was common to many steels, Table I. Subsequent investigation has shown that the mechanical properties before straightening may be recovered by a stress relieving heat treatment, but this is often inconvenient and may cause further distortion.

For quantity production rotary straightening has now largely succeeded the gag press and stretching. In a five-roll machine (Fig.2), the driven skew rolls rotate and feed the bar through the roll assembly. In each rotation each point of the bar within the machine is subject to a strain cycle, the peak strain in each cycle varying through the series of rolls according to the roll settings. To affect straightening the outer fibres of the bar must be plastically deformed for one or more cycles and the minimum radius of curvature of the bar within the rolls must be less than the minimum radius of the initial out-of-straightness. In practice, plastic deformation occurs over a number of cycles and, as this is symmetrical about the axis, so are the resultant properties of the bar.

Because the axial strain of an element in a bar subject to bending is proportional to the distance of the element from the centroid plane of the section, the core of a bar may be elastically strained while the surface is plastically strained. On relaxing after plastic bending the residual surface stress is opposite in sign to the stress existing during bending so that, neglecting work hardening, the applied bending moment to initiate plastic deformation in the reverse bend is less than in the previous bend. Even with work hardening this is usually the case. The application of uniform tension, as in a tension test, to a bar with a residual body stress distribution will initiate further plastic deformation when the sum of the applied stress and the maximum residual tensile stress attains the flow stress, i.e. the LP will be reduced. Experiment has shown (Fig.3), that the body stresses are completely eliminated when the applied strain exceeds the strain corresponding to the flow stress by the elastic strain

#### SYNOPSIS

The reduction in mechanical properties by rotary straightening has been shown to depend on the degree of bending imposed by the pressure roll or the exit idler roll. With a heavy centre roll setting an increase in the number of passes reduces the properties of the bar. The effect can be qualitatively explained by reference to the Baüschinger effect and it is doubtful whether body stresses contribute.

At present the machine operators determine the straightening procedure and this varies between operators. The results of the investigation suggest that specified machine settings and number of passes may reduce the effects of straightening such that the properties could meet a limited specification without further heat treatment.

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corresponding to the maximum residual stress, e.g. if the steel has a modulus of  $13.5 \times 10^3$  tons/in² a residual compressive stress of 13.5 tons/in² will have no effect beyond the 0.1%PS. The depth of the plastically deformed region in rotary straightening usually does not exceed 25% of the radius. The residual body stresses are therefore of low value and they are further reduced by cyclic flexing of decreasing amplitude. So, while these stresses could reduce the LP they should not significantly alter the proof stresses, as indicated by a tensile specimen machined from the core of the bar.

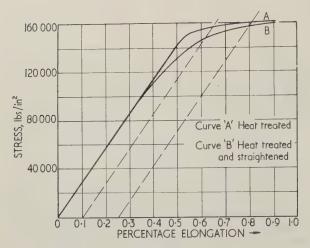
After plastic strain metal does not relax completely according to Hookes Law. Reverse plastic strain occurs whilst the original load is being removed. On reversing the load the modulus of the stress–strain relation continues to decrease and a limit of proportionality in reverse loading does not exist. This is known as the Baüschinger effect and is attributed to micro-stress set up by heterogeneous internal slip.

The material which has been plastically strained in bending will exhibit the Baüschinger effect and in subsequent tensile tests the LP and possibly the 0·1% and higher proof stresses may be reduced. Continuation of the tensile tests will relax the micro stresses until the stress–strain relation follows that of the unbent material. The fraction of the cross section exhibiting the Baüschinger effect will increase with the bending strain and so will have a greater effect on the overall properties of the bar.

If cyclic straining is continued for a number of cycles of small constant amplitude the area of the hysteresis loop in the stress-strain relation decreases over the first few cycles and afterwards remains constant. With a larger amplitude of cyclic strain the

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The authors were with the University of Sheffield when this paper was written. Dr Wallace is now with Pressed Steel Ltd, Cowley, Oxford.



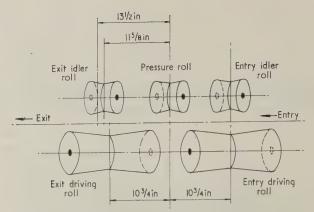
1 Effect of rotary straightening on stress-strain curve of En26 steel

overall effect of this relaxation and of work hardening can only be discussed for a particular material.

## EXPERIMENTAL EXAMINATION OF THE EFFECT OF ROTARY STRAIGHTENING ON THE MECHANICAL PROPERTIES OF En26 BAR

#### Operation of a five-roll rotary straightening machine

The Bigwood 1A five-roll machine used for the experiments on §in dia. bar, has two fixed driven skew rolls at  $27\frac{1}{2}^{\circ}$  to the pass line and three idler rolls which can be adjusted for angle, mesh, and station along the pass line. The bar passes through the machine at about 45 ft/min with 11 rev/ft length. The technique of straightening varies with the operator. The first idler roll is used only for severely bent bars while the centre idler, or pressure roll, is rarely moved from a point midway between the driving rolls. Some operators alter the position of the exit idler for different diameters of bar while others adjust this roll to compensate for wear. The extent and position of roll wear varies between operators. Whereas some prefer to work with the lines of contact of the bar and the rolls close together others prefer to work on the shoulders of the rolls. The number of passes of a bar through the rolls depends on the initial curvature in the bar, the operator's method of working and his decision whether the straightness is acceptable for the next process. With the five-roll machine the last 15in or so of the bar pass through the rolls without being straightened and for this reason the bars are turned end to end between each pass. Even so, it is often necessary to follow this straightening by a pass through the two-roll reeler which will not accept appreciably bent bar but will straighten over the whole length to a high degree of straightness.



2 Five-roll rotary straightener, Diagram showing the displacement range of the exit idler roll

Only five-roll machines were used in the experiments. The  $2\frac{3}{4}$ in dia. bar was reeled to commercial practice while for the  $\frac{5}{8}$ in dia. bar the mesh of the centre roll and the pass line position of the exit roll were calibrated and varied and each bar received a known number of passes following heat treatment. No absolute measure of straightness has been taken beyond the opinion of the operator that the straightness is acceptable or not.

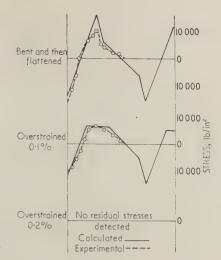
#### Mechanical properties across a section of straightened bar

The tensile test figures for a bar is normally for a specimen machined from the core. In the heat-treated condition the core is usually softer than the surface, the 'as heat treated' test figures being a minimum for the section. In rotary straightening only a fraction of the diameter is plastically deformed and therefore according to the diameters of the original bar and test pieces the properties shown by a tensile test will be more or less affected by the heat treatment effect and the effect of rotary straightening.

To examine the distribution of properties across a commercially heat-treated and straightened bar a 23 in dia. bar of En26 was heat treated and straightened by four passes through a Bigwood 3A five-roll straightening machine. Specimens machined from the 'as heat treated' and straightened bar, as shown in Fig.4, show (Fig.5) that the centre of the bar is unaffected by straightening, whilst there is a marked reduction in LP and proof stresses towards the surface. In this large-diameter bar the reduction in properties by straightening is comparable with the reduction arising from the differential rate of cooling heat in treatment. On the other hand, with a small-diameter bar, where the rate of cooling is more uniform and the properties are substantially constant across a section, the change in the minimum properties of the bar due to rotary straightening will be more significant.

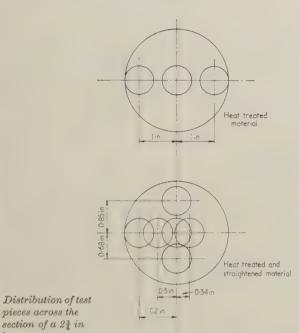
TABLE I Effect of rotary straightening on mechanical properties of alloy steel bars

Material	LP	Proof stress 0·05%	0.1%	0.2%	0.5%	MS	%El.	% R of A
S11, as HT	47	50·4	50·7	51·3	52·1	59	$23 \cdot 8$ $24 \cdot 1$ $24 \cdot 2$ $22 \cdot 2$ $22 \cdot 5$ $22 \cdot 0$	65·8
S11, straightened	22	40·3	45·1	48·1	50·8	58·1		66·8
En16, as HT	46	49·7	49·7	49·9	50·2	58		63·2
En16, straightened	27	38·4	40·7	42·9	46·0	57·3		63·2
En24, as HT	46	50·3	50·6	51·1	51·9	61·7		59·2
En24, straightened	27	46·9	47·6	49·8	52·3	61·3		59·2



Effect of tensile overstrain on residual stresses

pieces across the

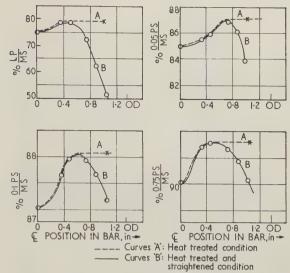


#### EXAMINATION OF THE EFFECT OF CENTRE ROLL MESH, EXIT ROLLER SETTING AND NUMBER OF PASSES ON THE PROPERTIES OF 5/8in Dia. En26 Bar

Hot rolled bars 5 in dia. and 12 ft long of En26 (S99) were prepared from a single known cast and heat treated at 880°C for 3 h, oil quenched, soaked at 580°C for 3½ h and air cooled. Tensile tests from a full length of 'as heat treated' bar show a graduation of properties along the bar (Table III). Nevertheless the

Recovering of properties by stabilizing treatment TABLE II

Condition	Av. % ratio LP MS	Av. % ratio 0.1PS MS
Heat treated	73.2	88-2
Heat treated and straightened	61.9	83.0
Heat treated, straightened, stabilized at 200°C	64.0	85.9
Heat treated, straightened, stabilized at 550°C	67-0	88.5



Effect of straightening across the section of a 2\frac{3}{2}in bar

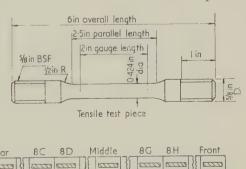
ratios of LP, 0.1%PS, and 0.25%PS to the maximum stress is almost constant and so these ratios have been adopted for experimental comparisons.

Before straightening, each 12-ft bar was identified and cut into 6-ft lengths. Control specimens were taken from each end of the 6-ft bars leaving about 5 ft for the experimental straightening. A 5-ft bar and a 12-ft bar were similarly straightened and specimens taken excluding the end 18in of each bar. Comparison of the results

12-ft bar ratio 0.1% PS/max. stress=82.78% 5-ft bar ratio 0.1%PS/max. stress=82.7%

justifies the use of the shorter bar for the experiments. After straightening, two adjacent specimens were cut from the centre of each 5-ft length. The tensile results quoted are the average for each pair of specimens. The tensile specimens (Fig.6) were of a form not conforming exactly to BS.18 (1950), For the majority of tests a 2in gauge length Lindley extensometer was employed in a 50-ton multi-lever testing machine operated at a nominal straining speed of 0·lin/min.

Special care was taken in machining the specimens to minimize working of the surface and modification of the residual stresses. Grinding, which is known to introduce high-tensile stresses on the surface, was avoided, the gauge length being fine turned and polished. The choice of the half bars for a series of experiments was such as to indicate experimental



Position of test pieces in bar no.8 and geometry of test pieces

TABLE III Variation of properties along a bar

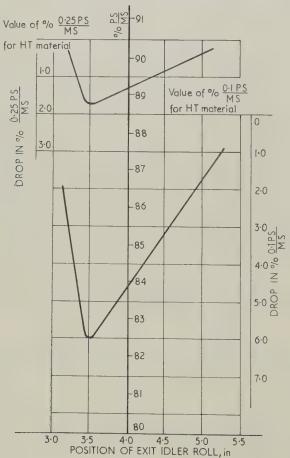
	$_{ m tons/in^2}^{ m LP,}$	0·1%PS, tons/in <sup>2</sup>	MS, tons/in <sup>2</sup>	$\%\frac{\mathrm{LP}}{\mathrm{MS}}$	% 0·1PS · MS.	% R of A	% El.	Izod, ft/lb
Front	63·0	$70.0 \\ 71.7 \\ 75.2$	79·6	79·6	87·94	55·05	16·75	36
Middle	65·7		81·4	80·6	88·1	53·7	16·7	32.
Rear	68·6		85·3	80·5	88·14	52·8	15·7	26

effects irrespective of probable differences in the properties of the full bars.

#### **EXPERIMENTAL RESULTS**

The change in stress-strain characteristic shown in Fig.1, was obtained by giving three passes through the machine with the centre roll set 5 in into mesh. Tables IV and V show the effect of centre roll setting and number of passes over a range exceeding normal operation. Even allowing for differences in the 'as heat treated' properties it is seen that a single light pass produces a substantial drop in LP. Comparison of bars numbered 4CD and 4GH shows that repeated light straightening gives a considerable recovery in the LP. It is interesting to note the apparent anomaly between the larger drop in LP with one and two passes at the  $\frac{5}{16}$  in setting compared with the  $\frac{15}{32}$  in setting. In the absence of further evidence no attempt is made to explain this effect but among factors which should be considered are depth of plastic region in the bar, work hardening and work softening.

In contrast to the effect of straightening on the LP,



7 Effect of position of exit idler roll on small bars

Table V shows that the 0.1%PS of the tensile specimens is unaffected by a centre roll setting of  $\frac{15}{32}$ in or less irrespective of the number of passes. Bars given three passes at the  $\frac{15}{32}$ in setting were accepted by the operator as straight. With the  $\frac{5}{3}$ in setting a single pass gives an appreciable drop in 0.1%PS which increases with the number of passes.

The tests of variation of centre roll mesh and number of passes were with the exit idler set in the standard setting of  $12\frac{1}{2}$  in from the pressure roll centre. The position of the exit idler roll affects the bending over the second driving roll and the range of adjustment of the roll is set by the safety limits of the angle of emergence of the bar. In further experiments, bars were straightened at the  $\frac{5}{8}$  in mesh roll setting. Three passes were given. As shown by Fig.7 the position of the exit roll has a substantial effect on the tensile properties of the bar. Adjustment of the roll by 0.4 in reduces the drop in 0.1% PS from 6% to  $3\frac{1}{2}\%$  and similarly, but to a smaller degree, the 0.25% PS. Throughout the range of roll settings an acceptably straight bar was obtained.

#### DISCUSSION

The experiments on the  $2\frac{3}{4}$ in dia. bar showed that the effect of rotary straightening is confined to the outer regions of the bar. In machining of a tensile specimen from the  $\frac{5}{8}$ in dia. bar the diameter is reduced over the

TABLE IV Influence of straightening schedule on limit of proportionality

$\frac{\text{LP}}{\text{MS}}$ Deflection	Numbe	r of passes	3	4	5
l in	79.0	79.7	78.2	75.8	79.6
1 in 5 in 16 in 15 in	57.9 $63.6$	53.8 $59.3$	$59.4 \\ 58.4$	65·8 48·8	$76.5 \\ 49.4$
5 in	47.2	50.1	43.4	47.6	49.1

TABLE V Influence of straightening schedule on 0·1% proof stress

$\frac{\%0.1PS}{MS}$ Deflection	Numbe	r of passes	3	4	5
1 in 1 in 1 in 1 in 2 in 3 in 4 in	87·6	87·8	88·0	87·9	87·9
	86·9	87·8	87·9	88·4	88·0
	87·2	87·2	87·1	88·3	86·3
	84·7	82·9	82·3	82·4	81·7

TABLE VI Influence of straightening schedule on 0.25% proof stress

$\frac{0.25PS}{MS}$ Deflection	Numbe	r of passes	3	4	5
1 in 5 in 16 in 18 in 18 in 18 in	90·9	90·9	90·4	90·0	90·0
	89·9	90·5	90·5	90·2	90·5
	90·3	90·3	90·5	89·7	89·9
	89·5	88·5	88·5	87·8	87·7

gauge length and the properties exhibited in a tensile test are those of the remaining material. The region of plastic deformation from a light reeling pass may not extend to the diameter of the gauge length of the test piece and for this reason the tensile results would not show any effect from the straightening process. The depth to which the LP is affected will be greater than the effect on the 0.1%PS and similarly this again will exceed that on the 0.25%PS, Table VI. This would explain the apparent threshold values for the effect of the centre roll setting on these properties.

In the 'as straightened' condition the whole section of bar would be expected to show a greater reduction in properties than as determined from the machined tensile specimens. Nevertheless, high tensile bar is rarely used in the unmachined state and the tensile tests are considered to give a reliable indication of the useful properties that could be expected from a component machined from the bar, e.g. a stud.

In special cases, to obtain the desired proof stresses in a component it may be necessary to use a larger diameter bar than the minimum required for the outside diameter of the component. Even so, it is doubtful whether the 'as heat treated' LP could be obtained without using a bar of excessive diameter, in which case the reduced properties of the core from heat treatment may outweigh the freedom from straightening effect.

#### **ACKNOWLEDGMENT**

The authors are indebted to the close co-operation of the English Steel Corporation Ltd, who also provided the material and reeling facilities.

## High-strength austenitic stainless steels

K. J. Irvine, B.Sc., Ph.D., D. T. Llewellyn, B.Sc., A.I.M., and F. B. Pickering, A.Met.A.I.M.

#### INTRODUCTION

THERE IS a continuing demand for high-strength stainless steels and although satisfactory transformable steels are available, there would be considerable interest in stronger austenitic stainless steels. Standard austenitic steels combine adequate corrosion resistance with ductility so that the steel can readily be formed, but may have 0.2% proof stresses of about only 14–18 tons/in² at room temperature. Although this level of strength can be considerably increased by cold working, ductility becomes too low to allow fabrication, and the improved mechanical properties cannot be retained at elevated temperatures.

The possibility of developing precipitation-hardening austenitic steels has always seemed attractive because the material would be soft and ductile in the solution-treated condition and hence easily fabricated. After fabrication the steel could then be hardened by an ageing treatment at a temperature of say 650–700°C at which temperature scaling should not be a problem. Although high strength can be obtained using precipitation hardening from a ferrite or martensite structure, a similar level of strength has not yet been obtained from an austenitic structure. For instance, alloy carbides produce appreciable secondary hardening when precipitated from tempered martensite but little hardening is obtained from an austenitic

At this stage it should be stressed that many of the steels which are loosely described as precipitationhardening stainless steels are in fact transformed to martensite before ageing and therefore cannot be

#### SYNOPSIS

Some possibilities for producing high-strength austenitic stainless steels have been examined. It has been shown that solid-solution hardening effects are relatively slight apart from the interstital elements C, N, and B. In general, substitutional elements have an increasing effect on hardness as they become increasingly different from iron in interatomic distance. Since each of these alloying elements has an effect in contracting or expanding the iron lattice, they are extremely useful in controlling the coherency strains in any precipitation reaction.

It has been shown that precipitation reactions provide the best means of obtaining high strength in an austenitic stainless steel. If carbide precipitation is used, then the amount of hardening depends upon the total content of C+N+P. When this total content approaches 0.4 or 0.5% quite high strengths  $(60-70 \text{ tons}/\text{in}^2)$  can be obtained. Above 0.5% total addition, cellular precipitation occurs which reduces the ductility. Consequently the best combination of properties is obtained at a tensile strength level of about  $60 \text{ tons}/\text{in}^2$ .

Very attractive properties can be obtained from austenitic steels where an intermetallic compound is the precipitating phase. Typical steels have Ni–Al, Ni–Ti, or Ni–Al–Ti additions. The precipitation reaction occurs in the temperature range 750–800°C and therefore good high-temperature properties can be obtained. Providing the tendency to cellular precipitation is controlled a good combination of strength and ductility can be obtained. There is not a great deal to choose between the different systems but one preferred composition is 25%Ni, 15%Cr, 1%Al, and 2½%Ti. With this steel quite satisfactory mechanical properties can be obtained up to a tensile strength level of about 70 tons/in².

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Dr Irvine is Metallurgical Research Manager, Mr Pickering is Head of the Physical Metallurgy Section, and Mr Llewellyn is a Research Investigator in the Research and Development Department of the United Steel Companies Ltd.

TABLE I Analyses of experimental steels

Steel classification	Steel no.	Analysis C	Mn	Si	Cr ~	·Ni	Мо	w	v	N
Series 1										
Base composition	1	0.098	0.72	0.51	15.60	25.12				0.016
Effect of Si	2	0.101	0.63	2.06	16.05	24.80			***	0.019
	3	0.095	0.44	4.34	15.90	24.84	***	***	***	0.021
Effect of Mo	4	0.098	0.59	0.33	15.50	24.60	1.98	***	4 6 6	0.013
Ellect of Mo	5	0.090	0.55	0.44	15.95	24.94	4.10	***	• • •	0.014
	6	0.087	0.55	0.36	16.00	24.97	7-20	***	*** ,	0.011
	7	0.079	0.55	0.38	16.10	24.95	10.20	* * *	***	0.010
Effect of W	8	0.092	0.59	0.36	16.10	24.70		2.05		0.018
211000 02 11	9	0.116	0.59	0.36 %	16.00	25.04		4.10	***	0.019
	10	0.093	0.59	0.40	16.05	24.84	***	7.40	***	0.033
	11	0.098	0.56	0.51	16.00	24.88	• • •	10.04	***	0.018
Effect of V	12	0.088	0.69	0.49	16.25	25.04	• • •	***	1.95	0.023
	13	0.091	0.62	0.41	16.20	24.84	***	***	3.90	0·021 0·030
	14	0.099	0.74	0.61	16.15	24.88	***	• • •	6.88	0.030
		С	Mn	Si	Cr	Ni	Cu	Co		N
Series 2										
Effect of Ni	15	0.08	0.69	0.43	18.12	6.06	***	***		0.026
	16	0.08	0.65	0.37	18.08	8.24	***	***		0.022
	17	0.08	0.64	0.35	18.30	10.28	• • •	***		0.022
	18	0.08	0.67	0.44	17.96	12.12	• • •	• • •		$0.024 \\ 0.022$
	19	0.08	0.67	0.47	18.12	14.04	000	***		
Effect of Mn	20	0.09	2.00	0.43	17.70	9.92	***	***		0.024
	21	0.09	4.03	0.39	18.15	10.00	***	***		$0.022 \\ 0.027$
	22 23	0.08	6.00	$0.54 \\ 0.44$	18·39 18·12	$10.08 \\ 10.04$	***	***		0.024
	24	0.07 $0.07$	$9.88 \\ 15.00$	0.41	18.00	10.00	***	•••		0.028
Tarre I C.C.								5.1	e.	0.021
Effect of Co	25 26	$0.09 \\ 0.08$	$0.56 \\ 0.46$	$0.37 \\ 0.34$	18.64 18.17	10·08 10·12	***	10.3		0.021
	27	0.08	0.49	0.36	18.12	10.12	***	14.9		0.020
Effect of Cu	28	0.08	0.55	0.38	18.24	9.94	1.92			0.021
Ellect of Cu	29	0.08	0.55	0.39	18.24	9.92	4.96	***		0.022
		C	Mn	Si	Cr	Ni	N	В		(C+N)
Series 3					***					
Effect of N at 0.08%C		0.08	0.64	0.35	18.30	10.28	0.022			0.102
,,,	31	0.08	0.65	0.43	20.30	9.88	0.137	•••		0.217
	32	0.08	0.66	0.43	18.45	10.15	0.260	***		0.340
Effect of N at 0.2%C	33	0.21	0.57	0.33	18.24	10.08	0.021	***		0.231
	34	0.21	0.62	0.31	18.00	10.07	0.136	***		0.346
	35	0.20	0.57	0.35	18.24	10.00	0.300	***		0.500
Effect of N at 0.4%C	36	0.41	0.60	0.29	18.24	10.24	0.025			0.435
	37	0.40	0.48	0.23	18.20	10.24	0.128			0.528
	38	0.40	0.53	0.26	17.72	10.08	0.309	***		0.709
Effect of B	39	0.08	0.55	0.26	17.80	10.44	0.026	0.01	0	•••
	40	0.09	0.61	0.31	17.74	10.28	0.026	0.04		***
	41	0.09	0.62	0.29	17.63	10.28	0.029	0.11		***
	42	0.09	0.59	0.40	17.70	10.20	0.028	0.19	3	

classified as austenitic. Such steels, which can be called 'controlled transformation' steels, have been described recently¹ and can give quite attractive properties. The properties however, depend upon complete transformation to martensite by a simple heat treatment and this requires such a critical control of chemical composition that the development of such steels has been limited. It would represent a considerable advance if similar mechanical properties could be obtained by precipitation from an austenitic matrix.

This paper describes work which has been aimed at the production of high-strength austenitic stainless steels.

#### EXPERIMENTAL RESULTS

#### Solid-solution hardening

Although the main part of the work of this paper was devoted to the study of dispersion or precipitation hardening it was felt that a preliminary study should be made of the solid-solution hardening effect of the alloying elements used.

Ferrite-forming elements

To study the addition of strongly ferrite-forming elements, a base composition of 0.1%C, 15%Cr, 25%Ni, 0.02%N was chosen so that up to 10% of Si, Mo, W, and V could be added without entering the delta-ferrite phase field. The analyses of these steels, and of all the other steels described in this paper are given in Table I. It was found that the alloys with more than 5%Si were too brittle to be forged, but all of the other steels were satisfactory. Solid-solution effects of elements like Nb and Ti are difficult to assess owing to the low solubility of NbC and TiC, which limits the solid solution hardening, but gives some degree of dispersion hardening.

Specimens from each steel were water quenched from solution-treatment temperatures of 1050°, 1100°C, 1150°, and 1200°C and the hardnesses measured. Figure 1 shows that there was a marked

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TABLE I Analyses of experimental steels (continued)

Steel classification	Steel no.	Analysis,	% Mn	Si	Cr	Ni	P		N	
Series 4										
Effect of P at 0.1%C	43	0.085	0.84	0.37	20.44	10.19	0.037		0.017	
,-	44	0.116	0.84	0.29	19.80	10.12	0.096		0.017	
	45	0.100	0.82	0.34	19.63	9.91	0.180		0.0130	
Effort of D -4 0 00/0	46	0.100	0.68	0.33	20.04	10.47	0.34		0.031	
Effect of P at 0.2%C	47 48	0·203 0·172	$0.55 \\ 0.79$	0·47 0·39	19.60	10.30	0.038		0.022	
	49	0.226	0.75	0.39	$20.21 \\ 20.10$	10·40 10·14	0·093 0·200		$0.0295 \\ 0.0295$	
	50	0.207	0.82	0.34	20.50	10.14	0.310		0.0285	
Effect of P at 0.4%C	51	0.420	0.81	0.27	20.30	10.12	0.016		0.0260	
	52	0.415	0.73	0.31	20.50	10.10	0.091		0.029	
	53 54	$0.410 \\ 0.392$	$0.72 \\ 0.73$	$0.27 \\ 0.31$	$\begin{array}{c} 20 \cdot 40 \\ 20 \cdot 30 \end{array}$	10.24 $10.32$	0.180		0.026	
Effect of P at 0.6%C	55	0.610	0.83	0.39	19.72		0.278		0.035	
21000 01 2 40 0 0 700	56	0.615	0.84	0.38	19.72	$10.22 \\ 10.20$	$0.011 \\ 0.067$		$0.0210 \\ 0.0210$	
	57	0.0590	0.78	0.41	19.62	9.72	0.210		0.0200	
		C	Mn	Si	Cr	Ni	P		N	
Series 5										
Effect of N at 0.2%C	58	0.17	0.79	0.39	20.21	10.4	0.093		0.030	
0·1%P	59	0.19	0.50	0.33	18.12	10.0	0.11	,	0.193	
	60	0.18	0.50	0.43	18.40	10.16	0.11		0.256	
Effect of N at 0.2%C	61	0.23	0.75	0.24	20.10	10.14	0.20		0.030	
0·2%P	62 63	0·19 0·18	0·55 0·55	$0.35 \\ 0.34$	$18.12 \\ 18.24$	$10.04 \\ 10.16$	0.18		0.180	
Effect of N at 0.2%C	64	0.20	0.62	0.44	20.0		0.20		0.326	
0.3%P	65	0.20	0.62	0.39	18.44	$9.95 \\ 10.12$	0.30 $0.32$		$0.038 \\ 0.184$	
70-	66	0.189	0.55	0.40	18.44	10.16	0.31		0.288	
		C	Mn	Si	$\mathbf{Cr}$	Ni	Al	To	tal N	Ni:Al rati
Series 6										
Cr-Ni-Al steels	67	0.056	1.10	0.45	15.65	25.04	0.78	0.0		32.1
	68	0.056	1.10	0.45	14.97	25.15	1.66	0.0		15.2
	69 70	0.050 0.051	$1.15 \\ 1.21$	0·43 0·53	15.42 $19.00$	24·96 30·10	$\frac{2 \cdot 47}{3 \cdot 00}$	0.0		10·0 10·0
	71	0.054	1.15	0.41	15.06	25.04	3.75	0.0		6.7
		C	Mn	Si	Cr	Ni	Ti	Мо	v	Total N
Series 7										
Cr-Ni-Ti steels	72	0.42	1.21	0.42	15.75	24.96	1.50	•••	***	0.016
	73	0.042	1.20	0.42	15.85	25.00	2.74	•••	•••	0.012
	74	0.040	1.19	0.37	15.32	24.92	3.85	• • •	***	0.011
		C	Mn	Si	Cr	Ni	Al	Ti	Total N	Ni:Al ratio
Series 8										
Cr-Ni-Al-Ti steels	75	0.049	1.18	0.43	15.37	24.96	0.98	1.28	0.021	25.5
2. 2.1. 221 21 000010	76	0.050	1.12	0.41	15.01	25.27	0.87	2.28	0.020	29.0
	77	0.024	1.16	0.60	16.40	25.09	1.72	1.53	0.024	14.6 $13.2$
	78 79	0·026 0·048	$1 \cdot 17$ $1 \cdot 31$	0.50 $0.52$	$16.40 \\ 16.20$	$25.04 \\ 25.29$	$1.89 \\ 2.72$	$\frac{2.50}{1.39}$	$0.028 \\ 0.020$	9.3
	80	0.036	0.95	0.53	15.35	24.92	2.95	2.75	0.048	8.4

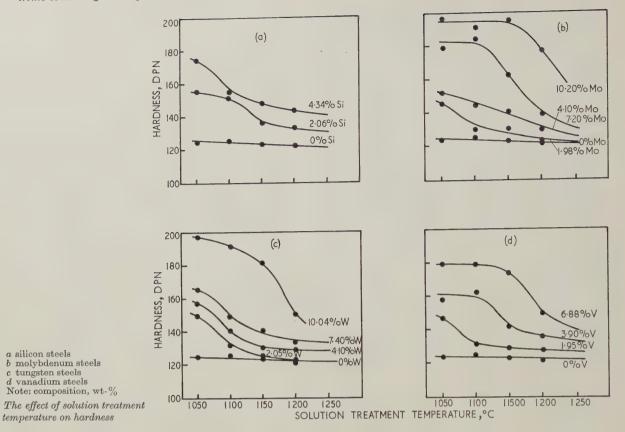
decrease in hardness in all the alloys with increasing solution temperature. This is because at low solution temperatures there were undissolved particles of intermetallic compounds which caused dispersion hardening. Higher solution temperatures dissolved these particles so that the dispersion-hardening effect was lost. Although the solid-solution hardening effect was increased, this did not offset the loss of dispersion hardening so that the resultant hardness was less. Therefore, solid solution hardening is less potent than dispersion hardening. At a solution temperature of 1200°C the structures were substantially free from precipitated compounds (except for the steels with 10%Mo and 10%W).

It was possible to add to these results, some further results obtained from series of steels containing Al and Ti which were used for the work on intermetallic compounds which are described in a later section of the paper.

The effect of alloy additions is to increase the solidsolution hardening effect as shown in Fig.2a, and these effects can be summarized as follows:

Element	$Hardness~increase \ DPN/at-\%$	Interatomic distance, $A^{\circ}$
Si	2.38	2.35
V	3.85	$2 \cdot 63$
Mo	4.00	2.72
W	4.10	2.74
Al	3.5	2.85
Ti	3.5	2.86

In general it is seen that the solid solution hardening is greater for the elements having a greater difference in atomic diameter from iron which has an interatomic distance of  $2.49 \text{ A}^{\circ}$ .



It is also interesting to examine the effect of the alloying elements on the lattice parameter of the austenite after solution treatment at 1200°C. This effect is shown in Fig.2b and a summary is given below:

Element	Change in lattice parameter/1 at- $\%$ , $kX$	Interatomic distance, $A^{\circ}$
Si	-0.0005	$2 \cdot 35$
$\nabla$	+0.0015	2.63
Mo	+0.0030	2.72
W	+0.0033	2.74

The change in lattice parameter is greater for the elements having a greater difference in interatomic distance from iron.

#### Austenite-forming elements

a silicon steels b molybdenum steels

tungsten steels d vanadium steels Note: composition, wt-%

temperature on hardness

For the study of the effect of austenite-forming elements, a base composition free from delta ferrite was necessary and 0.1%C, 18%Cr, 10%Ni, 0.02%N was chosen. Austenite of this composition has an Ms temperature sufficiently low to prevent transformation being produced by deformation during testing, and thus complicating the results. Additions of up to 15%Mn, 15%Co, and 5%Cu were made, and nickel was also increased up to 14%. Steels with copper contents greater than 5% could not be forged owing to hot-shortness. A solution temperature of 1050°C was sufficient to ensure complete solution, as few intermetallics were formed in these alloys.

The effect of the alloy addition on the solution treated hardness is shown in Fig.2c, and can be summarized as follows:

Element	$Hardness~increase \ DPN/at-\%$	Interatomic distance, $A^{\circ}$
Fe		2.49
Ni	0	2.48
Co	0.6	2.50
Mn	1.3	2.65*
Cu	2.96	2.55

<sup>\*</sup> Complex structure: difficult to assess.

The solid-solution hardening effect increases as the alloying element has a size increasingly different from iron.

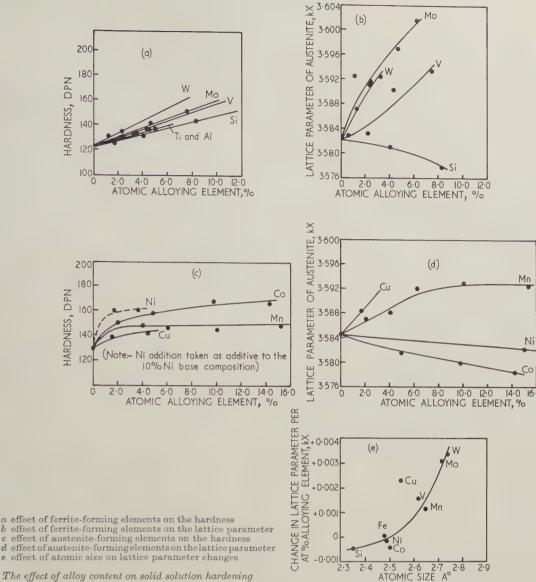
The effect of the alloying element on the lattice parameter is shown in Fig.2d. The range of nickel contents (10-14%) used in these steels was not very great so that it was difficult to assess the effect of nickel. It is helpful to compare the lattice parameters of the two widely different compositions given below:

Composition	Lattice parameter, $kX$
18%Cr 10%Ni	3.5845
15%Cr 25%Ni	3.5823

These results confirm that the effect of nickel, though very small, is slightly to contract the lattice. The effects of the austenite-forming elements are summarized below:

Element	Change in lattice parameter $ 1 \text{ at-}\%$ , $kX$	Interatomic distance, $A^{\circ}$
Ni	-0.00015	2.48
Co	-0.0004	2.50
Mn	+0.0011	2.65*
Cu	+0.0023	2.55

<sup>\*</sup> Complex structure: difficult to assess



#### The effect of alloy content on solid solution hardening

The change in lattice parameter is greater for the elements having a greater difference in interatomic distance from iron.

Comparison of the effect of substitutional elements

The results described above point to a relationship between the atomic size as measured by the interatomic distance, the solid-solution hardening effect, and the effect of the alloying element on the lattice parameter. The effect on the lattice parameter is summarized in Fig.2e. For atoms smaller than iron the parameter decreases and for larger atoms than iron the parameter increases.

The effect of these substitutional alloying elements on hardness and other mechanical properties of austenite is small. The important point, however, is that there are both ferrite- and austenite-forming elements which can expand or contract the austenite lattice. This should enable some measure of control to be exercised over the coherency strains in a precipitation-hardening austenitic steel (and hence over the intensity of hardening) while still retaining control over the constitution of the steel.

#### Interstitial elements

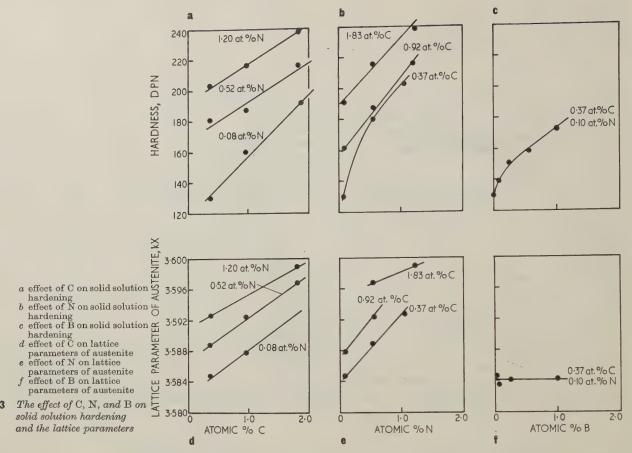
To complete the picture of solid solution hardening, the effect of the interstitial solid solution elements C, N, and B were examined. Steels were made using an 18% Cr, 10% Ni base to which additions of 0.02%, 0.14%, and 0.30%N were added at carbon levels of  $0.08\%,\,0.20\%,\,$  and 0.40%. Using an  $0.08\%C,\,18\%$  Cr,  $10\%Ni,\,0.02\%N$  base composition, B additions of up to 0.2% were also made. All the steels were fully austenitic and were rolled to \(\frac{3}{4}\)-in dia. bar.

Some work was carried out to determine the temperature which was necessary for complete solution of carbides and nitrides. These were found to be:

1050°C 0.08%C steels 0.20 %C steels 1150°C 0.40 %C steels 1200°C

It was found that providing the steels were water quenched from solution-treatment temperature there was little precipitation of carbides on cooling.

The effect of C, N, and B on the solution-treated hardness is shown in Figs. 3a, b, and c, and the effects are summarized below:



Element	Hardness increase DPN/1 at-%
C at 0.02%N level	41
C at 0·13%N level	25
C at $0.30\%$ N level	25
N at 0.08%C level	67
N at 0.20%C level	47
N at 0.40%C level	42
B at $0.08\%$ C, $0.02\%$ N level	44

The amount of solid solution hardening produced by these interstitial elements is much greater than that produced by substitutional elements: C and B have a very similar effect when related to the atomic percenage added, while N has a greater effect (which can be nearly twice as great). These effects cannot be directly related to the atomic diameters of the elements (C 1·80A°, N 1·82A°, B 1·96A°) but this is probably because these figures give no reliable indication of the size of the atoms when dissolved in austenite.

The effects of C, N, and B on the lattice parameter of the austenite are shown in Figs. 3d, e, and f, from which the following relationships can be obtained:

Elem <b>ent</b>	Change in lattice parameter/1 at-%, kX
C at 0.02%N level	+0.006
C at 0·13%N level	+0.0056
C at 0.30%N level	+0.0045
N at $0.08\%$ C level	+0.0084
N at 0.20%C level	+0.0092
N at 0.40%C level	+0.0030
B at 0.08%C 0.02%N level	Nil

With regard to C and N the changes in lattice parameter are in agreement with the amount of solid solution hardening observed. Nitrogen has a greater effect than carbon but both have a considerably greater

effect than any substitutional element. The likely explanation of the effect of boron is that the solubility of boron is very small and therefore there is no change in lattice parameter. The hardening effect is undoubtedly due to dispersion hardening by borides.

#### Mechanical properties

The main object of this work is to develop highstrength austenitic steels; the 0.20% proof stress in a tensile test provides a good indication of this. This value is more useful than the tensile strength which may be quite high as a result of work-hardening and possibly of transformation produced by the strain during testing. The mechanical properties obtained on these steels in the solution-treated condition are given in Table II. The hardness results previously described indicated that the solid-solution effect was not great and the tensile properties confirm this. The effect of the solid solution elements on the 0.2% proof stress is summarized in Fig.4. It will be seen that the results fall into three distinct groups of austenite- and ferriteforming substitutional elements and the interstitial elements. The most effective element is nitrogen and when this is present it is possible to double the 0.2%PS and obtain a value of 30 tons/in<sup>2</sup>.

#### Age-hardening steels utilizing a carbide precipitation

C+N steels

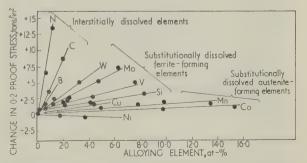
The most widely used hardening process in steels is the precipitation of a carbide, but this is usually from a ferritic structure where alloy carbides precipitate uniformly throughout the grains and attractive properties can be produced. In austenitic steels, however, the precipitation is more usually confined to

TABLE II Mechanical properties of steels in solution-treated condition

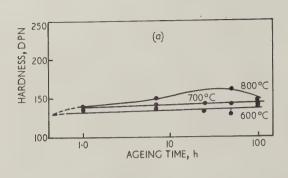
									_					
Ferrite forming elements														
Steel no.	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Alloy addition, %	Nil	2.06	4.34	1.98	4.10	7.20	10.20	2.05	4.10	7.40	10.04		3.90	6.88
		Si	Si	Mo	Mo	Mo	Мо	w	w	w	W	v	V	v
Solution-treatment temperate	ire 1050	oc wo												
TS, tons/in <sup>2</sup>	35.8	39.4	45.1	37.2	39.5	43.7	44.2	97 0	90.0	40.0	40 =	00.0	40.0	40.4
0.2% PS, tons/in2	14.2	16.8	19.8	15.2	16.8	20.6	21.4	37·8 15·5		$42 \cdot 2 \\ 19 \cdot 2$	46·5 22·4	$\frac{38.3}{16.4}$	40·8 19·3	43·4 20·6
0.1% PS, tons/in2	13.6	16.0	19.2	14.4	16.0	18.8	19.0	14.8		18.1	20.8	15.6	18.5	19.6
0.05% PS, tons/in <sup>2</sup> 0.02% PS, tons/in <sup>2</sup>	13.0	15.6	18.4	13.6	15-4	17.4	16.8	14.1	14.8	17.3	19.2	15.0	17.6	18.2
0.02% PS, tons/in <sup>2</sup>	12.4	15.0	17.2	12.8	14.4	16.0	14.4	13.1	13.6	16.0	17.2	13.6	16.4	16.8
Elongation on $4\sqrt{A}$ , %	55.0	56.6	67.0	56.0	56.0	51.5	35.1	50.5		52.6	45.6	56.0	52.8	47.6
R of A, %	69.6	77.4	70.8	73.6	$65 \cdot 6$	64.0	29.6	67-2		68.4	67.2	72.0	73.6	69.6
Impact, ft lb	187	152	129	127	92	82	29	112	118	118	86	129	150	116
Proof ratio (0.2% PS:TS)	0.40	0.42	0.44	0.41	0.43	0.47	0.48	0.41	0.41	0.45	0.48	0.43	0.47	0-47
Solution temperature 1200°	Z .													
TS, tons/in <sup>2</sup>	33.6	36.2	38.6	34.6	36.2	39.3	43.0	34.6	36.4	37.4	43.7	35.4	37.8	42.2
0.2% PS, tons/in2	12.8	14.4	15.8	14.0	15.2	17.8	19.8	13.3		14.8	17.6		15.5	17.8
0.1% PS, tons/in2	$12 \cdot 2$	13.8	15.4	13.2	14.4	17.0	18.9	12.6	14.2	14.2	16.8		14.4	16.8
0.05% PS, tons/in <sup>2</sup>	11.5	13.1	14.7	12.6	13.9	16.2	18.0	11.7		13.4	16.0	12.5	$13 \cdot 2$	15.7
0.02% PS, tons/in2	10.7	12.2	14.0	11.8	13.2	15.4	16.8	10.7		12.8	15.4		11.7	14.7
Elongation on 4\sqrt{A}, \%	58.3	65.2	84.4	58.5	67.7	49.4	$47 \cdot 1$	56.0		$62 \cdot 2$	57.8		57.8	55-8
R of A, % Impact, ft lb	75·2 188	78·6 195	77·4 190	75.2	68.4	65.6	52.8	73.6		75.2	72.0		77.4	68.4
Proof ratio (0.2% PS:TS)	0.38			169 $0.42$	156 2 0.48	$\begin{array}{c} 126 \\ 5  0.46 \end{array}$	$55 \\ 0.38$	162	181	181	172	206	199	141
1100114010 (0 2 /0 15.15)		0.40	) 0.41	0.42	0.46	0.40	0.99	0.4	1 0.40	0 •40	0 • 4	0 0.40	0.41	0.42
Austenite-forming eleme	nts													
Steel no.	15	16	17	18	19	20	21	22	23 2	4 25	26	27	28	29
Alloy addition, %	6.06	8.24	10.28	12.12	14.04	2.00	4.03	6.00						
Anoy addition, 70	Ni	Ni Ni	Ni	Ni Ni	Ni	Mn	Mn	Mn		5·00 5·3 In Co		30 14·9 Co	0 1.92 Cu	4.96 Cu
9-1 12 1 1	705	000 HIO												
Solution-treatment temperat		_	0= 4	0 = 0	0 = 4	00.0	0 = 0	0= 4	000	000			- 010	
TS, tons/in <sup>2</sup>	76.9	48·5 14·2	$37.4 \\ 14.2$	$35.9 \\ 14.1$	35.4	38.2	37.6	37.4				0.6 42.		
0.2% PS, tons/in <sup>2</sup> 0.1% PS, tons/in <sup>2</sup>	$21.8 \\ 21.8$	13.3	13.6	13.4	13·8 13·0	$15.8 \\ 15.2$	$\substack{15.7 \\ 15.0}$	$16.2 \\ 15.2$				$\begin{array}{ccc} 5 \cdot 0 & 15 \cdot \\ 4 \cdot 4 & 14 \cdot \end{array}$		
0.05% PS tops/in2	20.0	12.5	13.0	12.6	12.2	14.6	14.4	14.6				3·7 14·		
0.05% PS, tons/in <sup>2</sup> 0.02% PS, tons/in <sup>2</sup>	15.2	11.8	12.7	11.9	10.6	13.8	13.8	13.8				2.6 13.		
Elongation, %	41.1	70.8	77-6	72.4	65.5	72.7	61.7	75.5				3·8 76·		
R of A, %	40.0	69.6	73.6	75.2	75.2	69.6	69.6	68.4				8.4 70.		
Impact, ft lb	97	127	139	135	129	133	124	124		48 10			104	106
Proof ratio (0.2% PS:TS)	0.35	0.34	0.38	0.39	0.39	0.41	0.42	0.43					36 0.4	0 0.4
Interstitial alloy element	2			<del>M</del>										
Solution-treatment														
temperature, °C	1050					1150				12	200			
Steel no.	30		31	32		33	3	4	35	36	,	37	38	
	0.08		0.08	0.0		0.21		.21	0.20	0.		0.40	0.4	0
C, % Ni, %	0.08		0.03		260	0.021		-136	0.300		025	0.128		302
111, /0	0.022		0.191			0 021			0 000					
TS, tons/in <sup>2</sup>	37.4		42.2	4	9.8	42.4		46.5	51.6		8.5	52.8		6.8
0.2% PS, tons/in2	14.2		20.6		7.5	17.6		23.1	29.8		2.7	26.9		0.8
0.1% PS, tons/in2	13.6		19.5		5.4	16.9		21.9	27.6		0.9	25.4		9.8
0·1% PS, tons/in <sup>2</sup> 0·05% PS, tons/in <sup>2</sup>	13.1		18.6		4.2	16.3		20.7	26.0		9.0	23.7		8.6
0.02% PS, tons/in <sup>2</sup>	12.7		17.8		2.6	16.0		19.2	23.8		7.1	21.7		6.0
Elongation on 4\sqrt{A}, %	77.6		68.5		6.0	64.6		67.0	52.4		3.7	68.9		9.6
R of A, %	73.6		75.2		9.6	69.6		69.6	56.0		7.2	60.8	14	4·0
Impact, ft lb	139		160	16		122		41 0·49	159 0·4	a 12	0.47	137 0.51		o 0∙55
Proof ratio (0.2% PS:TS)	0.3	5	0.49		0.55	0.4	t 4	0.49	0.4	U	0.41	0.91		0.00

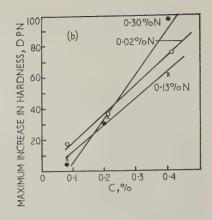
grain boundaries, especially at low C contents, and the hardening effect is less.

The amount of hardening which can be produced in a typical austenitic steel is shown in Fig.5a for a steel with the composition 0.08%C. This steel was solution treated at 1050°C before ageing. It can be seen that a hardness increase of about 30 DPN can be obtained after ageing for long times at 700-800°C. The microstructure which is shown in Fig.6a shows that there has been little or no precipitation within the grains but that there is a heavy concentration at the grain boundaries. The carbide which is precipitating is M<sub>23</sub>C<sub>6</sub>. Alloying elements, including strong carbide formers like Nb and Ti have little effect on this hardening process except to reduce it by lowering the active carbon. In such steels, however, slight hardening does occur at somewhat higher temperatures and can be markedly increased by warm working.

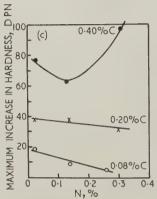


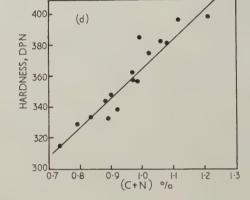
4 The effect of solid solution hardening in austenite (adequately solution treated)





- a ageing curves for base steel (18%Cr, 10%Ni, 0.08%C, 0.02%N)
  b the effect of C content on the ageing characteristics
- the ageing characteristics at  $800^{\circ}\mathrm{C}$
- the effect of N content on the ageing characteristics at 800°C
- d the effect of (C+N) content on the hardness after ageing of 21%Cr, 4%Ni, 9%Mn steel at 775°C for 16 h
- The effect of carbon and nitrogen on the ageing of austenitic steels





The amount of hardening which can be obtained from an austenitic steel by precipitation of  $M_{23}C_6$ depends very much on the amount of C and N which is in solution. Ageing experiments were carried out on the steels with a base composition of 18% Cr, 10% Ni, and varying carbon and nitrogen which were used for the investigation of the effect of interstitial elements on solid solution hardening (Series 3 in Table I). These steels were aged after an appropriate solution treatment. The amount of age hardening was negligible in times up to 100 h at temperatures up to 600°C. At 700°C appreciable hardening occurred and the maximum aged hardness was obtained after about 100 h. Temperatures of 800° and 900°C produced maximum ageing in times less than 100 h. The maximum amount of ageing observed in each steel at each temperature is shown below.

	Hardness, DPN								
C, %	0.08	0.08	0.08	0.21	0.21	0.20	0.41	0.40	0.40
N, %	0.032	0.137	0.260	0.021	0.136	0.300	0.025	0.128	0.309
DPN									
Original	129	180	203	161	187	216	191	215	239
600°C max.	138	188	210	167	191	224	200	222	239
⊿H	9	8	7	6	4	8	9	7	6
700°C max.	142	187	225	216	237	271	364	358	364
⊿H	13	7	22	55	50	55	173	143	125
800°C max.	147	189	208	199	225	247	268	278	341
⊿H	18	9	5	38	38	31	77	63	102
900°C max.	146	180	201	187	217	241	250	264	285
⊿H	17	0	2	16	30	25	59	49	46

To obtain an indication of the relative effects of carbon and nitrogen the results obtained at an ageing temperature of 800°C have been summarized in Fig. 5b and 5c. In these graphs the maximum increase in hardness obtained by ageing is shown in relation to the carbon and nitrogen contents. There is a major effect due to carbon and a much smaller effect due to nitrogen. In fact at low carbon contents, increasing nitrogen tends to decrease the amount of ageing slightly. This is probably because an increasing nitrogen content can increase the solubility of carbon. When the nitrogen content becomes high, however, the precipitation of nitrides supplements the hardening effect of precipitated carbides.

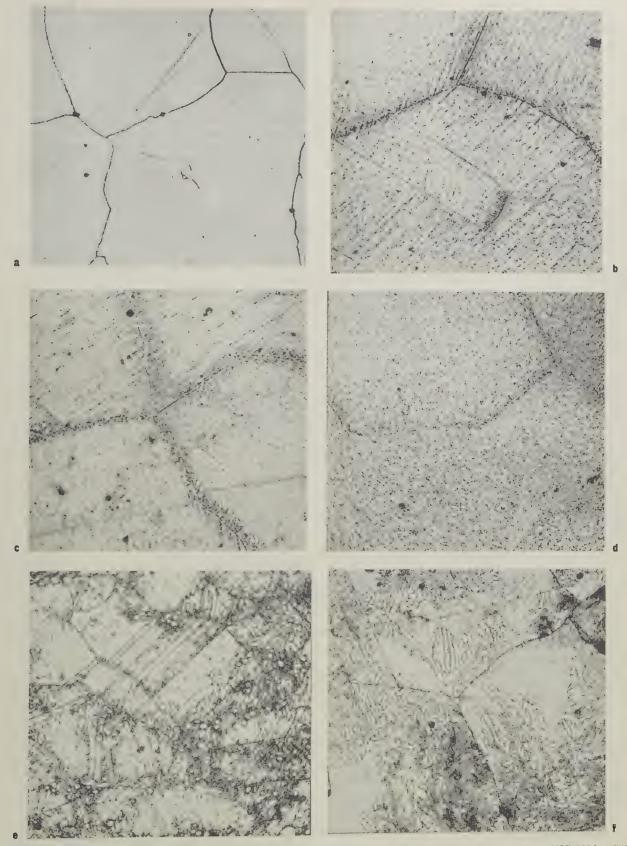
Microstructures (Figs.6b-d) show the increasing amount of carbide precipitation within the austenite

Mechanical properties were determined on all these steels after different ageing treatments between 700° and 800°C. The results obtained are given in Table III but the important features can be summarized as follows:

- (i) with ageing the tensile properties are increased but at the sacrifice of ductility and impact
- (ii) carbon is more effective than nitrogen in increasing strength, while high nitrogen contents produce greater reduction in ductility and
- (iii) ageing at 700°C produced the best proof stress values.

An indication of the range of properties which can be obtained in this way is shown by two steels with low and high carbon.

Heat treatment	0.21%C	0.41%C
1050°C WQ	, 0	70 -
Temp. 700°C, 100 h	$0.031\%\mathrm{N}$	$0.025\%\mathrm{N}$
TS, tons/in <sup>2</sup>	48.9	68.5
0.2% PS, tons/in <sup>2</sup>	20.9	$42 \cdot 1$
0.1% PS, tons/in <sup>2</sup>	19.3	37.7
0.05% PS, tons/in <sup>2</sup>	17.9	33.6
Elongation, $4\sqrt{A}$ , %	44.2	14.3
Reduction of area, %	51.2	20.8
Impact, ft lb	65	31



 $\begin{array}{l} \textbf{a} \ \ 0.08\%\text{C}, \ 0.02\%\text{N}, \ 18\%\text{Cr}-10\%\text{N} \text{i} \ \text{steel} \ \text{aged at } 650^{\circ}\text{C}-1\ \text{h} \ \times 750 \\ \textbf{c} \ \ 0.41\%\text{C}, \ 0.02\%\text{N}, \ 18\%\text{Cr}-10\%\text{N} \text{i} \ \text{steel} \ \text{aged at } 800^{\circ}\text{C}-100\ \text{h} \ \times 750 \\ \textbf{c} \ \ 0.41\%\text{C}, \ 0.02\%\text{N}, \ 18\%\text{Cr}-10\%\text{N} \text{i} \ \text{steel} \ \text{aged at } 800^{\circ}\text{C}-100\ \text{h} \ \times 750 \\ \textbf{c} \ \ 0.41\%\text{C}, \ 0.02\%\text{N}, \ 18\%\text{Cr}-10\%\text{N} \text{i} \ \text{steel} \ \text{aged at } 800^{\circ}\text{C}-100\ \text{h} \ \times 750 \\ \textbf{c} \ \ 0.53\%\text{C}, \ 0.037\%\text{N}, \ 18\%\text{Cr}-10\%\text{N} \text{i} \ \text{steel} \ \text{aged at } 800^{\circ}\text{C}-100\ \text{h} \ \times 750 \\ \textbf{c} \ \ 0.56\%\text{C}, \ 0.041\%\text{N}, \ 21\text{Cr} \ \ 4\%\text{N} \text{i} \ 9\%\text{N} \text{M} \text{n} \ \text{steel} \ \text{aged at } 775\text{C}-16\ \text{h} \ \times 750 \\ \textbf{c} \ \ 0.56\%\text{C}, \ 0.041\%\text{N}, \ 21\text{Cr} \ \ 4\%\text{N} \text{i} \ 9\%\text{N} \text{M} \text{n} \ \text{steel} \ \text{aged at } 775\text{C}-16\ \text{h} \ \times 750 \\ \textbf{c} \ \ 0.56\%\text{N}, \ 21\text{Cr} \ \ 4\%\text{N} \text{i} \ 9\%\text{N} \text{M} \text{n} \ \text{steel} \ \text{aged at } 775\text{C}-16\ \text{h} \ \times 750 \\ \textbf{c} \ \ 0.56\%\text{N}, \ 21\text{Cr} \ \ 3\%\text{N} \text{N} \ \text{c} \ 10\%\text{N} \text{N} \ \text{c} \ 10\%\text{N} \text{N} \text{N} \text{c} \ 10\%\text{N} \text{c} \ 10\%\text{N}$ 

6 Microstructures of age-hardened austenitic steels containing carbon and nitrogen

It is possible to use higher carbon and nitrogen contents than those described above and results have been obtained on a different austenite base composition (21%Cr, 4%Ni, 9%Mn, which has some importance as the basis of a commercial value steel 21/4 NS) using carbon contents between 0.4 and 0.7% and nitrogen contents between 0.3 and 0.6%. An interesting effect which was observed was that an increasing nitrogen content caused an increased amount of carbon to be taken into solution at any solution temperature. This was presumably because nitrogen when entering the interstitial sites in the austenite, expands adjacent sites to allow greater solution of carbon. Consequently, although nitrogen does not have such a marked effect as carbon, in high-carbon steels nitrogen and carbon can be regarded as roughly equivalent, owing to the effect of nitrogen in controlling the solution of carbon.

An ageing time and temperature which produced a marked effect in these steels was 16 h at  $775^{\circ}$ C. Figure 5d shows that a linear relationship was obtained between the aged hardness and the (C+N) content, which supports the conclusion drawn above.

In these high (C+N) steels the ageing process produces a very heavy precipitate in the austenite matrix as shown in Fig.6e. X-ray examination of electrolytically extracted residues showed that the precipirate was  $M_{23}$ C<sub>6</sub> with the added possibility that nitrogen was precipitating as Cr2N. As the nitrogen content increases, however, a lamellar precipitate becomes more evident, and very high carbon contents also produce the same effect. This lamellar structure which is clearly shown in Fig.6f is a form of cellular precipitation which occurs by means of a recrystallization reaction in the matrix when the strain during age hardening reaches a critical amount. Increasing nitrogen and carbon increases the amount of this cellular precipitation because they increase the coherency straining in the matrix. It is interesting that the relationship between hardness and C+N content does not show any major difference whether the lamellar precipitate is present or not, which indicates that the dispersion-hardening effect of this structure is equivalent to that of the separately precipitated carbides.

#### C+P steels

Evidence was available to show that phosphorus could increase the precipitation-hardening effect produced by carbide precipitation.<sup>2</sup> To examine this effect in more detail a 20%Cr-10%Ni base composition was chosen and steels were made containing C contents of 0.1, 0.2, 0.4, and 0.6%. At each of these carbon levels, steels were made with 0.03, 0.1, 0.2, and 0.3%P. These steels form Series 4 in Table I. All of these steels could be forged satisfactorily apart from the 0.6%C--0.3%P steel, which broke up. To ensure effective solution the following temperatures were used:

%C	$^{\circ}\mathrm{C}$
0.1	1050
0.2	1150
0.4	1200
0.6	1250

The important features of the ageing curves obtained can be summarized quite briefly. The optimum ageing temperature was found to be  $700^{\circ}$ C and peak hardening occurred in about 10 h. Figures 7a and b show

the effect of increasing carbon at a fixed phosphorus content, and also the effect of increasing phosphorus at a fixed carbon content. Both carbon and phosphorus increase the age hardening and they have almost equivalent effects. This equivalency can be shown by considering the ageing curves for steels with combined C+P contents of 0.2, 0.4, and 0.5%, which are shown in Fig.8. It will be seen that the amount of hardening is limited when the C+P content is only 0.2% but is quite marked when the combined content is 0.4 or 0.5%. Typical microstructures are shown in Fig.9. The important features are the general precipitation of carbides within the grains (Figs. 9a-d) and the appearance of cellular precipitation in the high-Chigh-P steels (Fig.9e). In the high-C-high-P steels the matrix precipitate is very fine and often occurs on dislocations (Fig.9f) which indicates that the hightemperature properties should be good.

The lattice parameter of the different composition austenites was measured to determine the effect of phosphorus:

Composition	. Lattice parameter, $kX$
0·1%C 0·02%P	3.5854
0·1%C 0·2%P	3.5852
0·1%C 0·3%P	<b>3.</b> 5850
0.4%C 0.02%P	3.5953
0·4%C 0·2%P	3.5951
0.4%C 0.3%P	3.5940

It can be seen that while carbon increases the lattice parameter, phosphorus reduces it.

X-ray diffraction identified the precipitate as  $M_{23}C_6$ . Chemical analysis of these extracted precipitates gave:

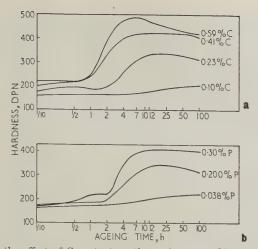
	Residue	analysis
Steel composition	C, %	P, %
0.2%C 0.02%P	5.44	0.33
0.2%C 0.1%P	5.91	0.40
0.2%C 0.2%P	5.01	2.51
0.2%C 0.3%P	4.53	5.19

With increasing phosphorus in the steel there is a reduction in the amount of carbon and an increase in the amount of phosphorus in the precipitate, which indicates that it is of the form  $M_{23}(C+P)_6$ .

Mechanical properties were determined on these steels after different ageing treatments between 700° and 800°C and the results are given in Table III. The tensile properties are closely related to the hardness changes which have already been described. The maximum effect is produced after ageing at 700°C. At each of the three carbon levels there is an increase in tensile strength with increasing phosphorus content and at the highest carbon, highest phosphorus level (0·39%C, 0·278%P), the tensile strength is increased above 80 tons/in². With increasing tensile strength there is an associated decrease in ductility and impact resistance; it is concluded that the combination of strength and ductility is only satisfactory up to 60 tons/in².

#### C-N-P steels

It has been shown that to a large extent there is an approximate equivalence between C and P and C and N in austenitic steel, and it was decided therefore to investigate the combined effects of C+P+N. This was done at a constant C level of 0.2% so that appreciable age hardening could be obtained, and



- at the effect of C content on the ageing at 700°C in 0.2%P, 20%Cr, 10%Ni steels b the effect of P content on the ageing at 700°C in 0.2%C, 20%Cr, 10%Ni steels
- 7 The effect of carbon and phosphorus contents on the age hardening of austenitic steels

additions of up to 0.3%P and 0.3%N were made. These steels are in Series 5 in Table I. A solution treatment of  $1159^{\circ}C$  WQ was adequate to produce an austenitic structure in these steels.

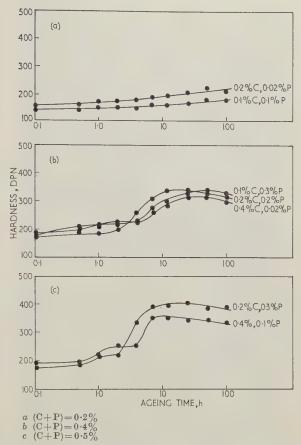
The maximum ageing occurred in the range 650–700°C in times of the order of 100 h. In the 0.1%P steels, increasing N from 0.03 to 0.2% produced an increased ageing effect, but a further addition of N to 0.3% did not give much more ageing. Increased ageing was produced when P was raised to 0.2% but once again the effect of increasing nitrogen dropped off when N was raised above 0.2%. Ageing again increased when P was raised to 0.3% and at this level of 0.2%C, 0.3%P, increasing nitrogen did not effect the maximum aged hardness very much.

It was observed that increasing phosphorus had a very marked effect on the hardness which could be obtained at very high ageing temperatures of the order of 750–800°C. This was due to a marked resistance to overageing of these high-P steels and showed one advantage of these structures which were heavily dispersion hardened.

The effect of C+P+N on the maximum aged hardness at 650° and 700°C is shown in Fig.10. It can be seen that phosphorus had a much greater effect in promoting ageing than nitrogen. In fact as the phosphorus content increases the effect of nitrogen decreases. It is to be expected that there is unlikely to be a direct equivalence between C, N, and P as the complexity of the alloy increases, and further work is now being carried out to examine these ageing effects in more detail. The results presented do give a very good indication, however, of the amount of ageing which can be obtained from C+N+P steels.

The microstructures of these steels were very similar to those which had been obtained with the C+P steels. Cellular precipitation was observed at C+P+N level of 0.5%, which is rather lower than in the C+P steel.

The mechanical properties were determined in a number of different aged conditions with ageing temperatures between 700° and 800°C. The results are given in Table IV, and it can be seen that tensile strength values of 70 tons/in² together with an 0.2%



8 The combined effect of carbon and phosphorus on the ageing of a 20%Cr, 10%Ni steel at 700°C

proof stress of 50 tons/in² can be obtained with adequate tensile ductilities of about 20% elongation, but at the expense of an impact value of not more than 15 ft lb. Better ductility results were obtained from the steels low in nitrogen.

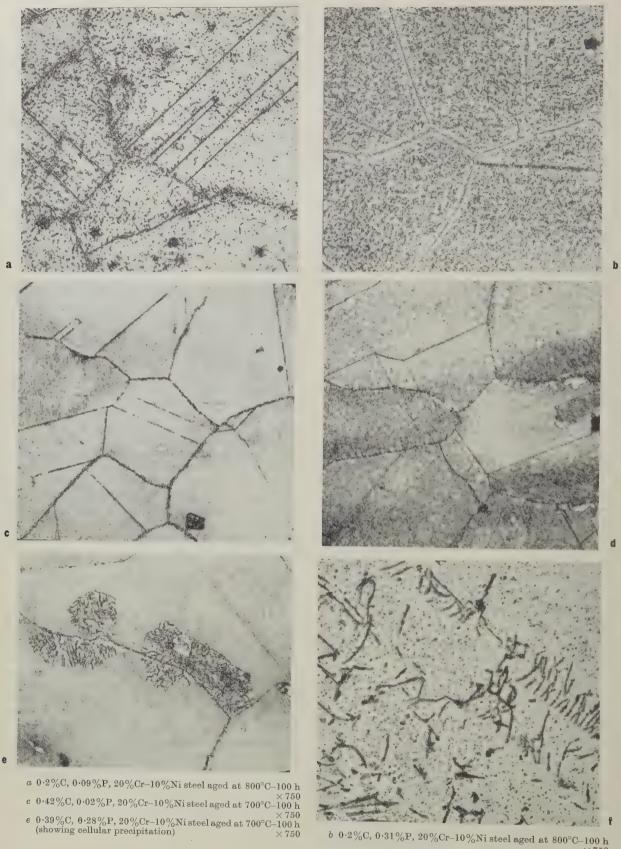
### Age-hardening steel utilizing an intermetallic compound precipitation

Ni–Al steels

One of the very successful age hardening systems in nickel-base alloys is the Ni–Al system and appreciable age hardening can be obtained from the precipitation of NiAl<sub>3</sub>.<sup>3</sup> It was therefore decided to investigate the similar precipitation from an austenitic stainless steel base. For this work a base composition of 0.05%C, 15%Cr, 25%Ni was chosen, the carbon content being kept low so that carbide precipitation would not interfere with the intermetallic compound precipitation. Steels were made with nominal Al contents of 0.75, 1.5, 2.5, 3.0, and 3.75%. These steels form Series 6 in Table I.

Specimens were solution treated at 1050°C and water quenched. The solution-treated hardnesses were:

Al, %	DPN
Nil	122
0.78	126
1.66	132
2.47	136
3.00	154
3.75	165



b 0.2%C, 0.31%P, 20%Cr-10%Ni steel aged at 800°C-100 h  $\times$  750 d 0.42%C, 0.09%P, 20%Cr-10%Ni steel aged at 700°C-100 h  $\times$  750  $\times$  750

 $\begin{array}{c} \text{$f$ 0.21\%C, \ 0.21\%P, \ 20\%Cr-10\%Ni \ steel \ aged \ at \ 850^{\circ}C-1 \ h} \\ \text{$(\text{showing precipitation on dislocations})} & \times 15000 \end{array}$ 

9 Microstructures of age-hardened austenitic steels containing carbon and phosphorus

The greater hardening effect of aluminium when present in amounts greater than 2.5% is probably due to the presence of some undissolved intermetallic compound which added some dispersion hardening.

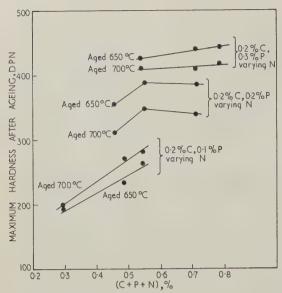
A typical series of ageing curves is shown for the steel containing 3.75% Al in Fig.11a. Appreciable age hardening occurs with ageing temperatures between 600° and 700°C in times between 10 and 100 h. Overageing is rapid at 750° and 850°C. Comparisons of the ageing curves for the different steels at tempera-

tures of  $600^\circ$ ,  $650^\circ$ , and  $700^\circ\mathrm{C}$  are given in Figs.11b–d. It will be seen that there is no ageing effect with the 0.75 and  $1.5\%\mathrm{Al}$  steels. Quite marked ageing occurs with the higher aluminium steels, however, so that it is possible to obtain an increase in hardness of the  $3.75\%\mathrm{Al}$  steel of 150 DPN by ageing for 10 h at  $700^\circ\mathrm{C}$ .

It has been mentioned that the high aluminium steels had intermetallic compounds out of solution after a solution treatment of 1050°C. Comparative

TABLE III Mechanical properties of C-N and C-P steels after ageing

	roperties o	r C-N and	U-P Ste	eis art	er age	ing							
C-N steels													
Steel no. 3	3 ·21	34 0·2	1		35 0·19	)	36 0·41			7	38		
N, %	-021	0.1	36		0.23	32	0.02	5		·40 ·128	0.5	309	
Ageing treatment temp., °C 7 time, h 1	00 750 00 25	800 700 25 100		800 25	700 100	750 80 25 25		750 25			800 70 25 10		800 25
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	8.9 48.8 0.9 21.4 9.3 19.3 7.9 18.2 5.7 16.4 4.2 43.4 1.2 47.2 5 73	48·0 53· 19·2 28· 17·8 26· 16·4 24· 14·4 22· 46·8 28· 52·8 29· 53 36	2 26.8 6 25.6 8 23.8 2 21.3 9 29.4	5 26.2 0 24.5 5 23.2 8 20.9 4 31.4	30.4 328.5 26.6 24.6 4 31.5	4 28·8 28 7 27·2 26 3 25·0 25 0 21·0 23 7 11·1 36	·1 42·1 ·6 37·7 ·2 33·6 ·3 28·8 ·4 14·3 ·0 20·8	32·0 28·8 25·4 21·0 22·8	29·4 4 26·9 3 24·0 3 20·6 3 31·8 36·0	9·3 32·9 6·5 29·6 2·0 24·9 7·4 9·6 9·6	33.7   43 $31.4   40$ $29.3   36$ $26.1   29$ $4.3   1$	·6 34·1 ·0 31·4 ·0 28·2 ·3 22·7 ·2 5·4 ·8 9·6	· · · · · · · · · · · · · · · · · · ·
C-P steels													
Steel no. C, % P, %		43 0·09 0·03				44 0·11 0·096				46 0·10 0·34			
Solution-treated 1050°C WQ  Tempering treatment		As quenched		750°C 7 h	800°C 1 h	As quenched		750°C	800°C	As quenched		750°C 7 h	800°C 1 h
TS, tons/in <sup>2</sup> PS, tons/in <sup>2</sup> for extension, %	0·2 0·1 0·05 0·02	41.7 16.8 15.8 15.0 13.9	42.9 18.1 16.7 15.5 14.2	43·1 16·3 15·0 14·0 12·5	41·4 16·0 15·2 14·5 13·4	39·3 15·8 14·9 14·0 13·0	39·9 15·9 15·0 14·2	$15.6 \\ 14.9$	39.6 15.4 14.6 13.8 12.7	46·3 18·9 17·8 16·8 15·4	61·2 45·1 43·4 38·9 35·2	60·2 37·4 35·3 33·0 29·6	50·7 26·4 24·6 22·9 20·6
Elongation on $4\sqrt{A}$ , % R of A, % Impact, ft lb	0.02	67.5 73.6 108	62·8 67·2 102	64.8	64·8 68·6 100	72·0 75·2 124	67·6 69·6 102	62.8	67·2 68·4 102	71.8 69.6 104	33·1 47·2 38	26·2 43·2 36	49·2 57·6 62
Steel no. C, % P, % Solution-treated 1150°C WQ		47 0·20 0·038				48 0·17 0·093				50 0·20 0·31			
Tempering treatment		As quenched		750°C 7 h	800°C 1 h	As quenched			800°C 1 h	As quenched		750°C 7 h	800°C 1 h
TS, tons/in <sup>2</sup> PS, tons/in <sup>2</sup> for extension, %	0·2 0·1 0·05	43·0 18·3 17·4 16·6	46.2 21.2 20.8 20.0 18.3	21·4 20·6 19·7	44.5 20.1 19.2 18.5 17.5	42·2 18·9 17·9 16·8 15·6	29·1 27·4 25·5		47.7 23.4 22.5 21.8 20.7	41.8 19.3 18.5 17.7 16.7	75·6 56·1 54·3 51·2 46·6	73.6 53.6 50.4 47.4 43.8	69·5 49·3 46·5 43·2 37·3
Elongation on $4\sqrt{A}$ , % R of A, % Impact, ft lb	0.02	15·4 72·5 70·8 131		18·4 52·0 54·4 86	60·7 64·0 108	74·2 75·2 133	42.5 47.2 65	45.0	55·6 56·0 94	73.6 80.6 141	12·5 16·4 9	19·3 23·2 12	27·2 29·6 15
Steel no. C, % P, %		51 0·42 0·016				52 0·41 0·091				54 0·39 0·278			
Solution-treated 1200°C WQ			70000	750°C	800°C	Ag	700°C	750°C	800°C	! As	700°C	750°C	800°C
Tempering treatment		As quenched		750°C 7 h	1 h	quenched			1 h	quenched			1 h
TS, tons/in <sup>2</sup> PS, tons/in <sup>2</sup> for extension, %	0·2 0·1 0·05	49·0 22·6 21·6 20·6	65·4 43·2 40·4 37·2	$34 \cdot 4 \\ 32 \cdot 0 \\ 24 \cdot 4$	53·0 29·8 28·4 26·8 24·6	48.2 $22.8$ $21.6$ $20.6$ $19.5$	52·8 48·0 43·0	68·9 44·3 40·0 36·0 30·6	63.0 $36.6$ $34.4$ $31.8$ $28.2$	$24.5 \\ 22.9 \\ 21.2$	83·0 73·6 69·2 63·4 55·4	78·2 68·8 64·0 59·4 53·0	73·4 64·2 60·1 55·3 47·6
Elongation on $4\sqrt{A}$ , % R of A, % Impact, ft lb	0.02	19·4 69·0 64·0 109	33·0 16·0 18·4 22	$29 \cdot 2$	36·9 36·0 26	$   \begin{array}{c}     19.5 \\     72.0 \\     67.2 \\     112   \end{array} $	21.2	22·5 27·2 14	29·1 29·6 15	75.5	1·4 4·0 3·5	1·0 4·8 3·5	0 PM 4·8 3·5



10 Effect of carbon, phosphorus, and nitrogen contents on age hardening 20 %Cr, 10 %Ni steels after ageing at 650° and 700°C

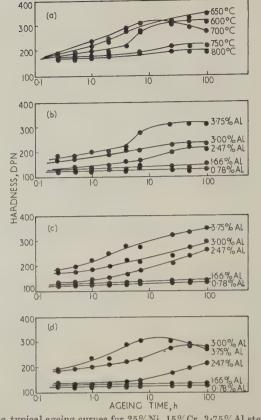
ageing tests were therefore carried out on the 3.75%Al steel with solution temperatures of  $1050^{\circ}$  and  $1200^{\circ}$ C and the following results were obtained:

	700°C		750°C		800°C	
Hardness						
Solution treated		Incre- ment	Peak aged	Incre- ment	Peak aged	Incre- ment
Solution to	reated 1	050°C				
164	312	148	215	51	195	31
Solution to	reated 1	200°C				
130	342	212	267	137	225	95

At the higher solution temperature of  $1200^{\circ}$ C, the initial solution-treated hardness is lower (owing to the loss of the dispersion-hardening effect of out-of-solution intermetallic compound) but the ageing effect is almost 50% greater at a temperature of  $700^{\circ}$ C.

The precipitating phases were identified by X-ray diffraction as  $M_{23}C_6$  and Ni Al. It is perhaps surprising that body-centred Ni Al should precipitate from an austenitic structure rather than face-centred Ni<sub>2</sub>Al, particularly since it is Ni<sub>3</sub>Al which precipitates from nickel-base alloys. The lattice parameter of the austenite matrix was 3.582 kX and the Ni Al was 2.878 kX. The microstructural changes during the ageing process were studied and some typical microstructures are shown in Fig.12. After ageing at 650°C for 100 h there were no obvious signs of general precipitation in the 2.5 and 3.75% Al steel despite the marked age hardening which had occurred. These two steels showed dense matrix precipitate when aged at 700°, 750°, and 800°C for 100 h (Figs.12a-c) and at these higher temperatures the precipitate was becoming over-aged, and developing a typical plate-like structure (Figs. 12d-f).

Mechanical properties were determined on these casts after solution treatment at 1050°C followed by ageing for 16 h at 700°C. These results are given in Table V. The effect of increasing aluminium is summarized in Fig.13, from which it can be seen that



a typical ageing curves for 25%Ni, 15%Cr, 3.75%Al steel b effect of aluminium content on age hardening at 600°C c effect of aluminium content on age hardening at 650°C d effect of aluminium content on age hardening at 700°C

11 The age-hardening characteristics of 25%Ni, 15%Cr steel containing aluminium additions

increasing aluminium content increases the tensile strength and 0.2% PS but decreases the ductility and impact values. Further tests to establish the optimum treatment for the 3.75%Al steel showed that after solution treatment at  $1150^{\circ}$ C and ageing for 16 h at  $700^{\circ}$ C the following attractive combination of properties could be obtained:

TS	70 tons/in <sup>2</sup>
0.2 %PS	50 tons/in <sup>2</sup>
Elongation on 4\sqrt{A}	20%
Impact, ft lb at 20°C	2.7

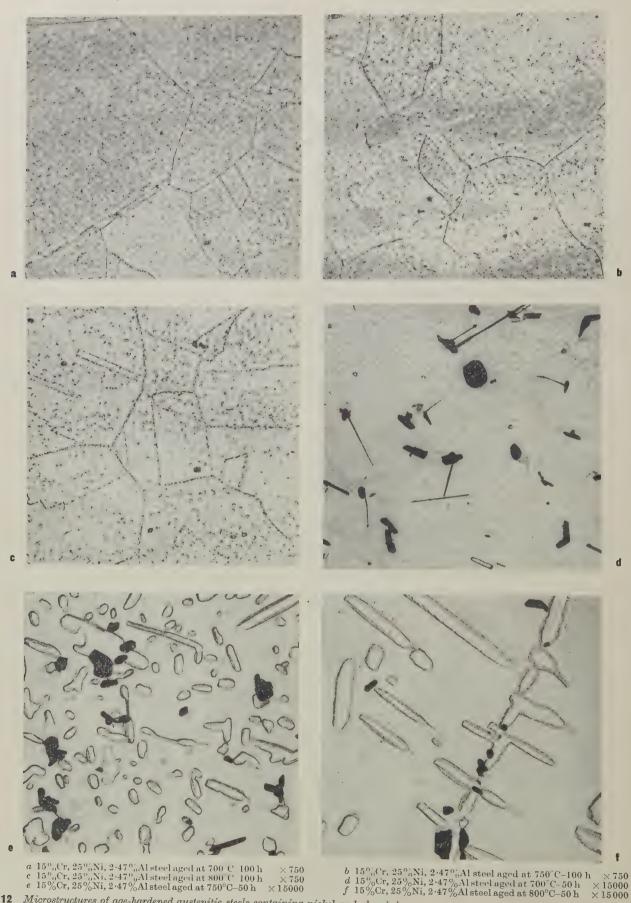
Since there are many similar features in the Ni-Al steels and the Ni-Ti and Ni-Al-Ti steels which are described below, discussion of these results is deferred.

#### Ni-Ti steels

Published results<sup>4-6</sup> show that marked age hardening can be obtained in at least four commercial austenitic alloys which contain titanium. These are Tinidur, Discalloy, A286, and Unitemp 212. These alloys are all based on 0.1%C, 13-16%Cr, 20-30%Ni, up to 2%Mn and 1%Si with additions of up to 3%Ti. Discalloy and A286 also contain up to 3.5%Mo and 0.5%V. To provide comparable results with the Ni–Al steels previously described, it was decided to investigate the effect of titanium additions to a standard austenitic base composition 0.05%C, 15%Cr, 25%Ni, 1%Mn, and 0.4%Si. To this base composition nominal titanium additions of 1.5, 2.5, and 3.5% were made.

ageing
s after
P steels
C-N-
properties of C-N-P ste
Mechanical
2
TABLE

Short no.   Steel no.   Stee	IABLE IV mechanical properties of U-M-r seeds and medical	roperties of		210010	מונמו	22															
Pi-0,   Pi-0	Steel no. C, % Ni %	58 0.17 0.03								69 0.19 0.193						60 0·18 0·256					
TS, tons   11	P. % Solution-treated 1150°C, 1 h	WQ and aged	I as shou			750°C	6 1	300°C	د تر	0.11 As	700°C	700°C 750	°C 750°C	1 h	800°C 25 h	As quenched	20.0	700°C 100 h	50°C 7	50°C 8	800°C 25 h
Engration, % on 614 32.2 32.6 45.0 38.3 55.6 39.0 70.8 38.6 29.0 44.4 25.3 52.0 41.4 62.8 27.5 27.5 27.5 27.2 32.0 17.0 Engration, % on 61 32.2 32.6 44.2 45.2 14.2 56.0 44.2 56.0 131 12 9 35 14 35 1	orextension, %	10.0			_	50.5 24.6 23.2 21.6	23.2 23.2 23.2 20.8	23.4 23.5 21.8 20.7	252.3 23.5 23.5 19.2	23.2 21.7 20.3 17.6	56.6 34.5 32.7 30.0 25.3	61.0 51. 36.8 27. 34.4 26. 31.2 24. 26.6 21.	8 55.6 7 31.3 3 29.8 8 28.8 8 26.7	50.3 26.0 24.8 23.2 21.0	53.3 28.0 26.4 24.2 21.5	49.9 25.0 22.9 22.0	56.1 32.0 31.3 29.4 26.4				29.6 27.5 27.5 25.1
Seel no.    Steel no.    Steel no.    Steel no.    Steel no.    O-23  Solution treated 1150°C 1 h WQ, and aged as shown quenched 25h 10h 7 h 25h 10h 25h 10h 47.8    Elongation, % on 43-2 20-6 35-6 35-8 20-6 20-6 35-1 21-8 27-8 27-8 27-8 27-8 27-8 27-8 27-8 27	uo %	_				45.0 47.2 64	38·3 47·2 60	55.6 56.0 94	39.0 47.2 60	70.8		1		52.0 54.4 35	41.4	62.8	27.5				34.0
Solution treated 1150°C 1 h WQ, and aged as shown As 700°C	Steel no. C, % Ni. % . P. % P. %	61 0.23 0.03 0.20								62 0·19 0·18 0·18						63 0·18 0·326 0·20					
TS, tons/in² (a) $\frac{43.2}{10}$ (b) $\frac{68.6}{4.5}$ (c) $\frac{64.6}{4.0}$ (c) $\frac{68.6}{4.0}$ (c) $\frac{64.6}{4.0}$	Solution treated 1150°C 1 h	WQ, and ag	ed as sha 70 shed 25		100 h	750°C 7 h	25 h	800°C 1 h	25 h	As quenched		750°C 25 h			0°С h	As quenched	700°C 100 h	İ			800°C 1 h
Elongation, % on 53.5 20.5 20.5 20.7 26.1 21.8 25.4 27.8 63.0 1.4 23.2 29.6 67.2 4.0 9.6 12.0 E. of A, % on 43.2 29.6 32.0 40.0 27.2 40.0 40.0 52.8 4.0 23.2 18.4 29.6 67.2 4.0 9.6 12.0 E. of A, % on 102 20 24 27 32 29 124 4 5 6 9 110 4 5	,	10.07			68.6 46.4 43.6 40.8 36.8	64.2 39.3 37.0 33.8 30.0	64.6 40.2 37.8 35.2 31.1	63.0 40.0 37.8 35.5 31.5	62.4 35.7.8 32.9 28.8	23.4 22.4 21.0 118.6	53.8 53.2 48.0 36.1	69.0 49.4 46.5 43.2 36.9	34.2 34.2 31.2 27.2		0 % 1. 9 9 1.	53.1 27.6 26.0 24.2 21.6	70.6 59.2 52.9 42.6 27.9	722.0 5.00 5.00 4.04 6.8	711 448 39 57 75		68.0 445.7 442.3 37.4 28.2
		53.6 43.2			20.5 32.0 20	26.1 40.0 24	21.8	25.4 40.0 32	27.8 40.0 29	63.0 52.8 124	4.0	23.5	18.4		9.	67.2	4 0 4	9.6	12		7.5



12 Microstructures of age-hardened austenitic steels containing nickel and aluminium

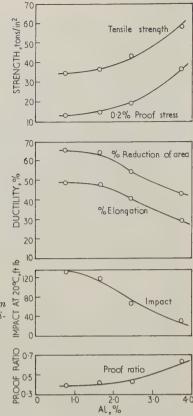
TABLE V Mechanical properties of Ni-Al, Ni-Ti, and Ni-Al-Ti steels after ageing

Steel no. Al, %	67 0·78	68 1.66	69	72				73				74			
Гі, %	0.10	1.00	2.47	1.50				2.74				3.85			
$Solution\ treated\ 1050^{\circ}C$ Ageing treatment, temp. $^{\circ}C$	700	700	700	700	700	750	750	700	700	770	==0	E00	W00	***	
time, h	16	16	16	16	100	16	50	700 16	700 100	750 16	750 50	700 16	700 100	750 16	750 50
Ni-Al, Ni-Ti steels															
$\Gamma S$ , $tons/in^2$ 0.2 PS, $tons/in^2$	$34.8 \\ 13.6$	$36.8 \\ 15.0$	43·0 19·5	39·9 19·2	$41.7 \\ 32.0$	39.9	43.6	66.7	72.4	66.0	63.8	76.2	77.8	76.4	59.7
0.1% PS, tons/in <sup>2</sup>	13.1	14.3	18.6	17.9	$30 \cdot 2$	$17.3 \\ 16.2$	$\frac{21 \cdot 4}{20 \cdot 1}$	$45.2 \\ 43.4$	$50.6 \\ 48.0$	$45.6 \\ 42.4$	$\frac{41.8}{39.7}$	$52.0 \\ 49.4$	$59 \cdot 3$ $53 \cdot 6$	$\frac{54 \cdot 2}{48 \cdot 4}$	30·6 25·8
0.05% PS, tons/in <sup>2</sup> 0.02% PS, tons/in <sup>2</sup>	$\frac{12.8}{11.7}$	$\begin{array}{c} 13 \cdot 2 \\ 11 \cdot 2 \end{array}$	$17.8 \\ 16.2$	$\begin{array}{c} 16.7 \\ 15.0 \end{array}$	$28.2 \\ 24.6$	$15.2 \\ 13.7$	18·9 16·9	$\frac{41 \cdot 1}{37 \cdot 7}$	$45.0 \\ 39.1$	$\frac{37.8}{30.2}$	$36.8 \\ 31.7$	$46.5 \\ 40.5$	$45.4 \\ 35.2$	$40.6 \\ 32.0$	21.6
Elongation on $4\sqrt{A}$ , % R of A, %	$49 \cdot 2 \\ 65 \cdot 6$	$48.0 \\ 64.0$	$41.0 \\ 54.4$	$43 \cdot 1$	$36 \cdot 1$	46.5	37.5	30.1	21.6	$22 \cdot 0$	$29 \cdot 3$	16.7	9.7	$12 \cdot 2$	17.6
mpact at 20°C, ft lb	134	118	67	67·2 113	56·0 82	65·6 131	64·0 116	36·0 56	32·0 53	25·2 58	43·2 58	$\frac{20.8}{36}$	$\frac{14 \cdot 4}{19}$	$\frac{12.0}{19}$	14·4 16
1100114010	. 0.39	0.41	0.43	0.48	0.77	0.44	0.49	0.68	0.70	0.69	0.66	0.68	0.76	0.71	0.8
li-Al-Ti steels	==														
Steel no. $\Lambda$ l, $\%$	75							76							
ri, %	0·98 1·28							$\begin{array}{c} 0.87 \\ 2.28 \end{array}$							
Solution temp., °C	1050	1050		050	1050		150	1050		050	1050		1050		50
Ageing treatment, temp. °C time, h		700 100		50 6	750 50		50 6	700 16		00 00	750 16		50 50	75 16	
$\Gamma$ S, $ ans/in^2$ $0.2\%$ PS, $ ans/in^2$	58·2 32·7	59·2 36·0		2.2	70.2		3.4	71.0		8.8	72-2		70.2	55	
·1% PS, tons/in <sup>2</sup>	32.0	34.9		$5 \cdot 6$ $4 \cdot 0$	45·8 43·8		9·2 8·4	41.6 40.8		$\begin{array}{c} 5\cdot 2 \\ 4\cdot 0 \end{array}$	$44.8 \\ 42.9$		$45 \cdot 2 \\ 43 \cdot 2$	28 27	
0.05% PS, tons/in <sup>2</sup> 0.02% PS, tons/in <sup>2</sup>	31·2 30·0	33·6 31·8		1·7 7·4	41·6 37·4		$7 \cdot 2$ $5 \cdot 6$	$\frac{40.0}{37.8}$		$2 \cdot 8$ $1 \cdot 2$	40·8 37·5		40·8 36·8	$\frac{26}{25}$	
Elongation, %	$26 \cdot 0$	28.9	2	4.9	23.5	1	9.6	27.5	2	8.6	28.5		$24 \cdot 1$	27	-2
R of A, % mpact, ft lb	43·2 55	49·2 65	3	6·0 8	36·0 81		$7 \cdot 2$	$\begin{array}{c} 38.0 \\ 62 \end{array}$	$\frac{4}{6}$	3 · 2 5	36·0 53		32·0 60	36 67	
Proof ratio	0.56	0.61	1	0.63	0.65	<u> </u>	0.55	0.59		0.60	0.62	2	0.64	0	-51
šteel no.	77							78							
Al, % Fi, %	$1.72 \\ 1.53$							$1.89 \\ 2.50$							
Solution, temp., °C	1050	1050		050	1050		150	1050		1050	1050		1050		50
Ageing treatment, temp. °C time, h		700 100	7	50 6	750 50	7	50 6	700 16		00 00	750 16		750 50	75 16	
TS, tons/in <sup>2</sup>	61.5	62.6		2.6	59.8		9.9	71-4		3 • 4	72.6		72.6	68	
0.2% PS, tons/in <sup>2</sup> 0.1% PS, tons/in <sup>2</sup>	$32 \cdot 2 \\ 31 \cdot 8$	36·4 35·6		4 · 4 4 · 0	$34.0 \\ 32.4$		1·6 1·2	$44.2 \\ 42.7$		6·8 5·2	44·0 42·4		$47 \cdot 2 \\ 45 \cdot 2$	40 38	
1% PS, tons/in <sup>2</sup> 05% PS, tons/in <sup>2</sup>	31·6 30·7	34·4 33·0		3·4 2·0	$\frac{31 \cdot 2}{28 \cdot 8}$		$0.4 \\ 9.2$	41.6 39.8		4·0 1·1	$40.8 \\ 37.6$		$43 \cdot 2 \\ 40 \cdot 8$	37 35	
·02% PS, tons/in²	31.7	$24 \cdot 2$	2	8.7	27.4	2	8.9	28.9	2	1.0	$26 \cdot 4$		21.4	28	.9
R of A, % mpact, ft lb	43·2 71	38·0 56	6	7·2 4	40·0 60	3 6	$\frac{2\cdot 0}{0}$	36·0 58	3	7·2	32·0 49		27·2 29	27 62	
Proof ratio	0.52	0.58		0.55	0.57		0.53	0.62		0.64	0.61		0.65		•59
teel no.	79							80							
AI, % Pi, %	$2.72 \\ 1.39$							$2.95 \\ 2.75$							
olution temp., °C	1050	1050		050	1050		150	1050		050	1050		1 050 750	1 1 75	50
ageing treatment, temp. °C time, h		700 100	10	50 3	750 50	1	50 6	700 16		00 00 	750 16		50 50	16	
S, tons/in <sup>2</sup>	61.6	66.2		0.1	60.1		4.4	70.1		1.6	• • •		69·4 42·4	72 47	
·2% PS, tons/in <sup>2</sup> ·1% PS, tons/in <sup>2</sup>	$35.7 \\ 35.2$	$41.2 \\ 40.0$		4·5 3·4	$35.2 \\ 33.6$	4	2·0 0·4	$44 \cdot 2 \\ 43 \cdot 2$	4'	3 · 0 7 · 2			40.2	45	.6
·05% PS, tons/in <sup>2</sup>	34.4	38-4	35	2.0	$38 \cdot 2$	4	2.0	$45.6 \\ 43.2$		5·6 3·2	***		$38.0 \\ 34.4$	44 40	
·02% PS, tons/in²	33·2 36·0	$35 \cdot 6$ $30 \cdot 0$		9·7 )·5	$\begin{array}{c} 35.8 \\ 22.8 \end{array}$	2'	9·8 7·1	23.0	23	3 ⋅ 0			22.4	17	- ]
of A, %	49.2	34·0 48		5.2	45·5 41	34	4 · 0 5	$\frac{36.0}{48}$	21 31	7 • 2 l	32		23·2 27	$\begin{array}{c} 23 \\ 24 \end{array}$	
mpact, ft lb Proof ratio	58 0·58	0.62		)·57	0.59		0.65	0.63		64			0.61		.66

These steels form Series 7 in Table I. These steels were solution treated at 1050°C and water quenched. The solution treated hardnesses obtained were:

Ti, %	DPN
1.50	127
2.74	131
3.85	136

These results show that the solid-solution hardening effect was slight. The ageing curves for one of the steels (2.74%Ti) are shown in Fig.14a, from which it can be seen that the most effective ageing temperatures are 650°, 700°, and 750°C. Comparisons of the ageing curves obtained with the different steels are shown in Fig.14b–d. Increasing titanium produced an increase in age hardening. An indication of the



13 Effect of aluminium content on mechanical properties of 25%Ni, 15%Cr steel after solution treating at 1050°C-WQ and ageing for 16 h 700°C

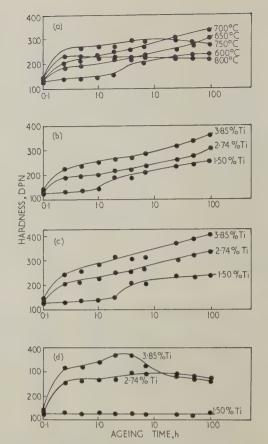
amount of ageing is given by the following results after ageing for 100~h at  $700^{\circ}C$ :

Ti, %	1.50	2.74	3.85
Aged hardness, DPN	235	334	405
Hardness change from solution-			
treated condition, DPN	108	203	269

Some typical microstructures are shown in Fig.15.

Ageing at 600° and 650°C produced very little change in the microstructure except for a slight grain boundary precipitate. At 700°C, ageing resulted in coalescence of the grain boundary precipitate, and differential etching of the grains was evidence that precipitation was occurring (Fig.15a). In the 3.85% Ti steel a cellular precipitation had occurred after 100 h at 700°C (Fig.15b). At 750°C, overageing was occurring after 10 h (Fig.15c). Cellular precipitation was beginning at the grain boundaries of the 2.74% Ti steel, and in the 3.85% Ti steel there was almost 100% cellular precipitation (Fig.15d). The main feature of the microstructures after ageing at 800°C was the cellular precipitation in the 2.74% and 3.85% Ti steels and the lamellae were coarser than at 750°C (Fig. 15e). X-ray diffraction identified the precipitates as TiC and Ni<sub>3</sub>Ti.

Mechanical properties were determined after a number of different ageing treatments; the results are given in Table V. It was found that 100 h at 700°C produced the highest strength. To enable a direct comparison to be made with the Ni–Al steels, however, the results are given in Fig.16 for an ageing treatment of 16 h at 700°C, the shorter time being a more practicable commercial treatment. Increasing titanium content increases the tensile strength and reduces the



a typical ageing curves for 25 %Ni, 15 %Cr, 2.74 %Ti steel b effect of Ti content on age hardening at 650°C c effect of Ti content on age hardening at 700°C d effect of Ti content on age hardening at 750°C

14 The age-hardening characteristics of 25%Ni, 15%Cr steels containing titanium additions

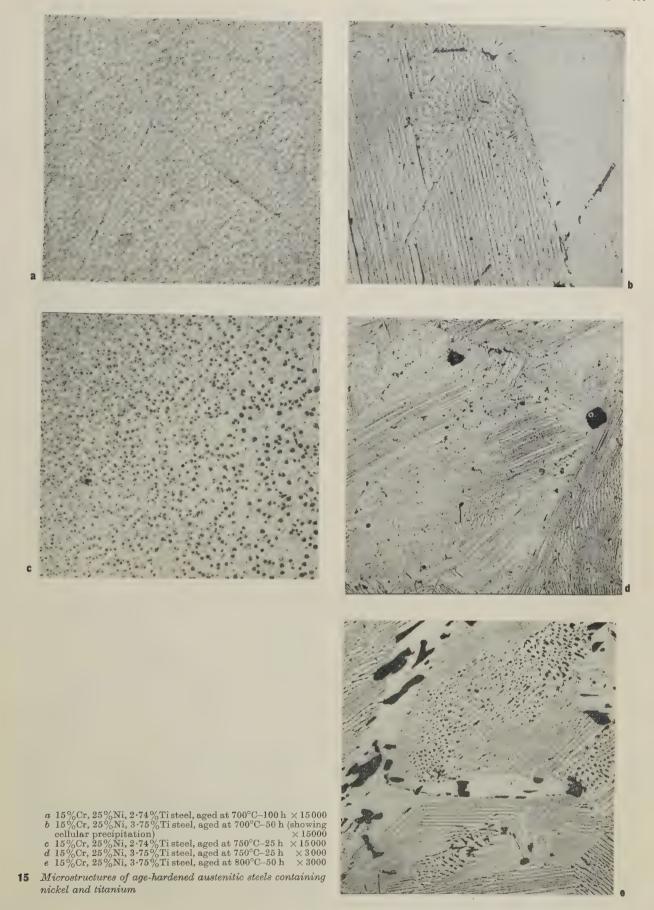
ductility and impact values. Some of the most interesting mechanical properties which can be obtained are given below:

Steel	2.74%1	ri .	3.84%]	Гi
Ageing treatment	16 h	100 h	16 h	100 h
	700°C	$700^{\circ}\mathrm{C}$	700°C	700°C
TS, tons/in <sup>2</sup>	66.7	72.4	76.2	77.8
0.2% PS, tons/in <sup>2</sup>	$45 \cdot 2$	50.6	$52 \cdot 0$	59.3
Elongation on $4\sqrt{A}$ , %	30.1	21.6	16.7	9.7
Impact, ft lb at 20°C	56	53	36	19

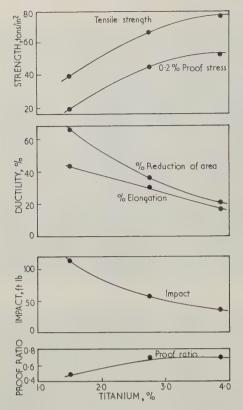
# Ni-Al-Ti steels

Since precipitation effects can be obtained from stainless steels containing Ni–Al and Ni–Ti, it is interesting to know what precipitation can be obtained when Ni–Al–Ti are present, especially as this combination is very effective in Nimonic alloys. The same base composition of 0.05%C, 25%Ni, 15%Cr, 0.02%N was used, and aluminium additions of 1, 2, and 3% were used at each of the titanium contents of 1.5 and 2.5%. These steels form Series 8 in Table I. Specimens were solution treated at 1050°C followed by water quenching.

Typical ageing curves for one of these steels (1%Al, 2.5%Ti) are shown in Fig.17a and it will be seen that these are similar to those obtained with the Ni–Al and Ni–Ti steels. Using an ageing temperature of 750°C, it is possible to show the effect of increasing



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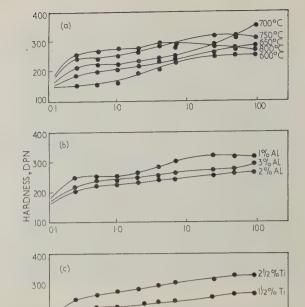
16 Effect of titanium content on mechanical properties of 25%Ni, 15%Cr steel after solution treating at 1050°C-WQ and ageing for 16 h at 700°C

aluminium and titanium in Figs. 17b and c. The main effects can be summarized as follows:

- (i) the ageing curves show a two-stage ageing process
- (ii) a small aluminium content (up to 1%) increases the age hardening of a titanium bearing steel, but further additions of aluminium tend to decrease the amount of age hardening
- (iii) increasing the titanium content at any particular aluminium content increases the agehardening
- (iv) the amount of ageing in a Ni–Al–Ti steel is greater than can be obtained with the single addition of similar amounts of aluminium and titanium
- (v) the optimum composition therefore, contains a low aluminium and high titanium content, and of those tested, the steel containing 1%Al, 2.5%Ti gave the best results. The comparison between the maximum aged hardness obtained in times up to 100 h for this Ni–Al–Ti steel and Ni–Al and Ni–Ti steels is given below:

Compe	sition	Maxim	Maximum hardness DPN obtained at								
AI, %	Ti, %	$600^{\circ}\mathrm{C}$	$650^{\circ}\mathrm{C}$	$700^{\circ}\mathrm{C}$	$750^{\circ}\mathrm{C}$	800°C					
0.87	2.28	259	290	356	320	292					
0.78	* * 5	125	125	128	120	120					
	2.74	235	304	334	294	232					
3.75		308	340	312	215	195					
	3.85	385	354	405	380	340					

The only steel giving superior hardness values is the 3.85%Ti steel.



ACEING TIME,h

a typical ageing curves for 25%Ni, 15%Cr, 1%Al 2.5%Ti
steel

100

b effect of Al content on age hardening of 25%Ni, 15%Cr, 1.5%Ti steel at 750°C c effect of Ti content on age hardening of 25%Ni, 15%Cr, 29%Al steels at 750°C.

17 The age-hardening characteristics of 25%Ni, 15%Cr steels containing aluminium and titanium additions

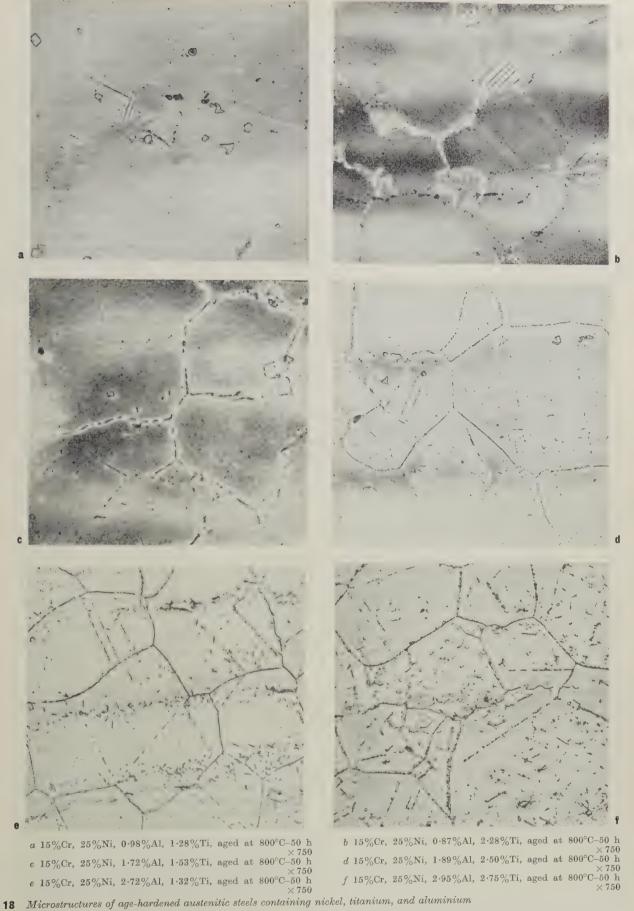
The precipitating phases were identified by X-ray diffraction of extracted residues. To obtain easy extraction the specimens were overaged at 800°C for 100 h.

It was found that both face-centred cubic Ni<sub>3</sub> (Al Ti) and body-centred cubic Ni (Al Ti) were precipitated depending on the Ni:Al ratio. These results are summarized below:

Compo	osition					
			(Al+Ti),	Ni/	Ni/	Precipitating
Ni	Al	Ti	%	Al	(Al+Ti)	phase
$24 \cdot 9$	0.98	1.28	2.26	$25 \cdot 5$	11.0	Ni <sub>3</sub> (Al Ti)
$25 \cdot 27$	0.87	$2 \cdot 28$	3.15	29.0	8.0	Ni <sub>3</sub> (Al Ti)
25.09	1.72	1.53	$3 \cdot 25$	14.6	7.7	Ni (Al Ti)+
						Ni <sub>3</sub> (Al Ti)
25.04	1.89	2.50	4.39	$13 \cdot 2$	5.7	Ni (Al Ti)+
						Ni <sub>3</sub> (Al Ti)
$25 \cdot 28$	$2 \cdot 72$	1.39	4.11	9.3	6.1	Ni (Al Ti)
24.92	2.95	2.75	5.70	8.4	$4 \cdot 4$	Ni (Al Ti)

A comparison can be made with the results obtained with the Ni–Al and Ni–Ti steels. With high Ni/Al ratios or low aluminium contents the presence of titanium changed the precipitate from Ni Al to Ni<sub>3</sub> (Al Ti), so that titanium caused the bcc precipitate to be replaced by the fcc precipitate. With decreasing Ni/Al ratios or increasing aluminium content, both Ni<sub>3</sub> (Al Ti) and Ni (Al Ti) were formed. At the lowest Ni/Al ratio, or highest aluminium content, only Ni (Al Ti) was precipitated.

The microstructural changes in these steels had many of the features observed previously; typical structures are shown in Fig.18. Cellular precipitation



was observed in the 1%Al-1.5%Ti steel but not in the 3%Al-1.5%Ti steel. In fact cellular precipitation occurred in both the alloys which precipitated only Ni<sub>3</sub> (Al Ti), as shown in Figs. 18a and b, but not in the alloys which precipitated Ni (Al Ti). The Ni<sub>3</sub> (Al Ti) also formed as a fine general precipitate, which did not coarsen much on overageing. In contrast the Ni (Al Ti) precipitate, although a fine precipitate at low ageing temperatures, rapidly overaged to form massive plates (Figs. 18e and  $\hat{f}$ ).

With such similar ageing curves to those of the Ni-Al and Ni-Ti steels, similar mechanical properties would be expected from these Ni-Al-Ti steels apart from perhaps small differences in ductility and impact properties which can be related to particular microstructural features. Standard ageing treatments of 16 and 100 h at 700° and 750°C were used and the mechanical properties obtained are given in Table V. At this stage it is possible to make a comparison between the best properties obtained from the Ni-Al, Ni-Ti, and Ni-Al-Ti steels; this is given below:

	TS, tons/in <sup>2</sup>	0.2% PS, tons/in <sup>2</sup>	Elongation, %	R of A,	Impact 20°C, ft lb
Ni-Al steels	50	25	35	47	48
	60	36	26	34 .	27
	70	49	18	21	23
Ni-Ti steels	50	28	39	56	85
	60	36	30	42	63
	70	46	20	29	35
Ni-Al-Ti	50	24	37	60	75
steels	60	34	30	56	57
	70	44	23	31	38

While the proof stress values of the Ni-Al-Ti steel are lower at any given tensile strength level than either the Ni-Al or Ni-Ti steel the ductilities are better, and the impact values are comparable with the Ni-Ti steel and better than the Ni-Al steel.

One of the interesting features of the microstructure of many of these steels has been the formation of a cellular precipitate.

Cellular precipitation is now recognized as one of the general features of precipitation reactions, and has been known for some years under such names as 'discontinuous precipitation' and the 'recrystallization reaction'. Cellular precipitation usually nucleates at the grain boundaries and grows outwards as a nodule in which the matrix phase and the precipitate take a characteristic lamellar form. The matrix phase is a recrystallized form of the original parent phase, and the precipitate is a non-coherent form. Turnbull<sup>8</sup> considers cellular precipitation to be one of the most important mechanisms for producing non-coherent precipitates. During the growth of the cellular precipitate, the general precipitate within the matrix redissolves in front of the moving interface and the driving force for the reaction probably stems from the straining of the lattice caused by both the strains,9 produced by the general precipitation and also from thermal strains imposed during the solution treatment and subsequent ageing. That strain has a considerable effect on the rate of cellular precipitation is shown by the accelerating effect of applied deformation. The growth of the cellular precipitate is usually rapid owing to its low energy and also to the rapid rates of diffusion at the non-coherent interface. It has been

mentioned that the strains produced by general coherent precipitation probably form the driving force for the cellular precipitate, but these coherency strains are generally considered to be elastic. They can be sufficiently high, however, when coupled with thermal strains to promote some plastic deformation which in turn promotes the cellular precipitation.

Cellular precipitation can be regarded as a fairly stable form of dispersion hardening and as such shows considerable resistance to overageing. This effect can be useful in maintaining high strength levels either after high-temperature ageing or during elevatedtemperature testing. Unfortunately however, where there is a large amount of cellular precipitation, the ductility is usually low, especially the creep ductility, and such a precipitation reaction is usually suppressed if possible. This can be achieved either by adjusting the analysis so as to limit the age hardening to a level which does not cause enough strain for cellular precipitation to occur, by reducing thermal stresses by slower cooling rates after solution treatment, or by the addition of small amounts of elements such as B in steel, which probably neutralize the grain boundary nucleation sites.

# The design of age-hardening compositions

From the information given in earlier sections of this paper it can be seen how an age-hardening austenitic stainless steel can be designed. In the first place, it is useful to consider the part played by the base composition. It has been shown that solid solution hardening is slight and can largely be ignored from the point of view of a contribution to the room-temperature strength. It is known, however, that solid solution hardening has much more effect on high-temperature properties and, where this is important, elements like molybdenum may be useful quite apart from any effect that they may have on the precipitation reaction.

Although the solid-solution hardening effect is limited, the base composition is important because it is the relative lattice parameters of the matrix and precipitating phase which control the strain associated with the precipitation and have an important effect on properties like rupture ductility. The effects of the different elements on the lattice parameter of austenite have been described, and using this information it is possible to produce quite major modifications to a precipitation reaction. When a preferred age-hardening system has been selected therefore, it is possible to adjust the base composition to produce the best combination of strength and ductility.

Of the possibilities for age-hardening systems, the precipitation of a simple carbide has many limitations. Not only is the hardening effect slight (unless there is a high carbon content) but the precipitate overages rapidly at temperatures above 600°C. This means that the high-temperature properties are poor, and there are also likely to be troubles associated with reduction of strength in the heat-affected zone of welds unless complete re-solution heat treatments can be carried out. Better properties can be obtained from steels containing stable carbide formers such as Nb or Ti. In such steels the precipitation reaction occurs in the temperature range 750-900°C and the high-temperature properties are better. The amount of age hardening is still relatively small, however, so that the effect on the room-temperature properties is slight. Although such steels have satisfactory high-temperature strength they do have rather low rupture ductility particularly if high solution temperatures are used. This feature can also be troublesome in the heataffected zones of welds, particularly if strain associated with the weld intensifies the precipitation. This is one example where it is desirable to modify the composition of the steel in order to reduce the strain associated with the precipitation. Instead of the standard composition containing 18%Cr, 12%Ni, 1%Nb, it may be preferable to increase the lattice of the austenite by substituting manganese for some of the nickel, and to decrease the lattice of the carbide by substituting an element like molybdenum or vanadium for some of the niobium. In this way the degree of misfit is decreased and improved ductility will be obtained.

It is much preferable, however, to have an intermetallic compound as the precipitating phase. The ageing temperature is high at about 750-850°C and the precipitate is resistant to overageing. Good properties can be obtained both at room temperature and at elevated temperatures. One feature which must be controlled is the tendency to cellular precipitation. This can give rise to reduced ductility, although as a structure it is extremely resistant to overageing at high temperatures. Since the mechanism for the formation of cellular precipitation involves strain, its formation can be hindered by reducing the strain. This can involve the actual heat-treatment process (i.e. water quenching should be avoided) or the degree of misfit resulting from the particular austenite and precipitate lattice. A more certain method, however, is to limit the amount of precipitating phase: the results which have been presented indicate the maximum amount of Al or Ti that should be used.

In this paper results have been given for Ni-Al, Ni-Ti, and Ni-Al-Ti systems. There is not a great deal to choose between these, but both the Ni-Ti and Ni-Al-Ti steels are slightly better than the Ni-Al steels. The benefit is that of better ductility at the higher strength levels and there is a slight advantage in the Ni-Al-Ti steels. The preferred composition that would be selected from this work is 25%Ni, 15%Cr, 1%Al, 2.5%Ti. This steel has a good all-round combination of mechanical properties, and with the information which is available on the effect of individual alloying elements it should be possible to design modified compositions to meet specific requirements. In fact it is the composition which gives maximum age hardening combined with freedom from major amount of cellular precipitation. Increase in titanium above 2.5%, however, introduces unacceptable amounts of cellular precipitation.

#### **ACKNOWLEDGMENT**

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# Role of crystal structure on the ductility of pure iron at elevated temperature

Jack L. Robbins, O. Cutler Shepard and Oleg D. Sherby

# INTRODUCTION

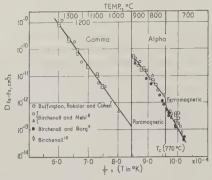
EXTENSIVE FUNDAMENTAL RESEARCH on high temperature strength properties of metals has contributed to a much greater understanding of the creep process from an atomistic viewpoint. It is now generally accepted that creep of most pure metals and dilute alloys is controlled by the rate of climb of dislocations which in turn is controlled by the rate of diffusion of atoms. An additional important factor controlling creep appears to be the high temperature modulus of elasticity.

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Mr J. L. Robbins is graduate research assistant, Mr O. Cutler Shepard professor of metallurgy, and Mr O. D. Sherby associate professor of materials science, at the Department of Materials Science, Stanford University, Stanford, California.

# SYNOPSIS

The torsional ductility of three pure irons was determined in the range 600–1200°C at a strain rate of 47% per second. The results indicate that alpha iron is considerably more ductile than gamma iron at elevated temperatures. Two factors contribute to the higher ductility of alpha iron. The major factor is due to the more rapid rate of diffusion of atoms in the more open bodycentred-cubic structure and the second factor is associated with the larger number of slip mechanisms in bodycentred-cubic iron in contrast to face-centred-cubic iron. The possible role of grain boundary shearing and recrystallization on ductility is discussed with respect to purity and temperature.



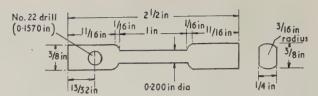
Self-diffusion rate of iron atoms in the alpha and gamma phases

These findings were first suggested by Kanter<sup>1</sup> and have been more extensively verified and hypothesized by others in recent years.2-5 No such parallel in experimental and theoretical development appears evident on an understanding of ductility properties of metals. This is in great part due to the fact that basic research on metallurgical variables affecting ductility of metals has been negligible.

Much of the early as well as recent effort on hot ductility studies in ferrous materials was performed primarily in the gamma range of temperatures. Sauveur, 6 however, did study the ductility behaviour of Norway iron in tension and torsion as a function of temperature from 600° to 1200°C. Unfortunately his tests were performed under a temperature gradient and therefore no definitive conclusions can be made as to the role of crystal structure and temperature on ductility. The present investigation was initiated to fill this important gap in our knowledge of the ductility of iron.

# MATERIALS AND EXPERIMENTAL TECHNIQUES

Three relatively pure irons were used in this investigation: Armeo ingot iron of 99.7% purity, Puron of  $99\cdot95\,\%$  purity, and electrolytic vacuum-cast iron of  $99\cdot97\,\%$  purity. The compositions are shown in Table I together with the annealing treatments used to get a constant ferrite grain diameter of about 0.05 mm. In order to compare the ductility of alpha iron with gamma iron under comparable conditions an attempt was made to test gamma iron at the same grain size. It was thought that this could be achieved by annealing the irons in the austenite range at a temperature



Torsion specimen

where the atomic self-diffusion rate was equal to the diffusion rate of atoms at the ferrite annealing temperature. Data for atomic self diffusivity in iron in the alpha and gamma phases are shown in Fig.1; these data supplied the information for heat-treating conditions for the gamma irons listed in Table I. Such specimens were heat-treated in the test furnace, taken directly to the test temperature and the ductility determined. It was possible to evaluate the austenite grain size for Armco iron by quenching from the annealing temperature into an iced NaOH solution after which the material was etched in a saturated solution of picric acid in ethyl alcohol. The grains were detected by the presence of impurities segregated at the former austenite grain boundaries and the mean grain diameter was about equal to 0.08 mm which is close to the corresponding ferrite grain size of 0.05 mm. Consequently the original basis for choice of annealing treatments in austenite appears to be essentially valid.

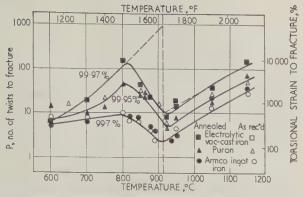
It was decided to use the torsional test method for the determination of ductility. Preliminary tests in torsion and tension indicated that considerably more scatter in values of elongation and reduction in area was obtained in tension tests. Early work in torsional ductility studies was performed by Clark and Russ<sup>11</sup> and Ihrig<sup>12, 13</sup> on iron base alloys in the gamma range. Analyses of the data obtained by these investigators is questionable. Solid rods, about 2 ft long, were used as test specimens and a temperature gradient existed over these rods which resulted in the presence of alpha and alpha plus gamma transformation regions as well as gamma regions. These factors were ignored by the investigators; undoubtedly such conditions complicated the analyses of the data obtained. The torsion test method for measuring ductility has been revived in recent years. 14-18

In this investigation, test specimens were machined to the dimensions shown in Fig.2 from 3in dia. rods. Heating was done in an 18in long tubular resistance furnace and temperature was maintained constant over the lin gauge length of the specimen to about

TABLE I Compositions and heat treatments of the three irons investigated

Material	Composition, wt-%								Heat treatments Alpha(a)			nts	s Gamma(b)		
	Fe	C	Cu	S	Mn	Si	P	0	Ni	T, °C	time, min.	grain dia., mm	T, °C	time, min.	grain dia., mm
Armeo ingot(e)	99-7	0.024	0.082	0.020	0.036	0.003	0.004	0.08	0.040	875	20	0.046	1147	20	0.084
Puron(d) Electrolytic	99.95	0.002	0.002	0.009	< 0.002	< 0.001	0.0008	0.040	< 0.004	875	20	0.059	1147	20	
vacuum-cast iron(e	99-97	0.0025	0.008				•••	0.0049	0.008	825	15	0.034	1075	15	

<sup>(</sup>a) Specimens air cooled after time at temperature

<sup>(</sup>b) Specimens taken to testing temperature directly after annealing treatments
(c) Other impurities as follows: Cr -0.004, Mo -0.011, Sn -0.007, As -0.007, V -<0.001, Al -0.001, Co -<0.001, and N -0.005.
(d) Other impurities as follows: Co -<0.002, Mg -<0.0008, Mo -<0.002, Zn -<0.01, Zr -<0.005, and Al, Ag, Ba, B, Cr, Ce, Ir, Pb, (a) Other impurities as follows: Co -<0.002, Mg -<0.0008, Mo -<0.002, Zn -<0.01, Zr -<0.005, and Al, Ag, Ba, B, Cr, Ce, Ir, Pb, (b) Other impurities as follows: Co -<0.002, Mg -<0.0008, Mo -<0.002, Zn -<0.01, Zr -<0.005, and Al, Ag, Ba, B, Cr, Ce, Ir, Pb, (c) Other impurities as follows: Co -<0.002, Mg -<0.0008, Mo -<0.002, Zn -<0.01, Zr -<0.005, and Al, Ag, Ba, B, Cr, Ce, Ir, Pb, (c) Other impurities as follows: Co -<0.002, Mg -<0.0008, Mo -<0.002, Ng -<0.002, Ng -<0.003, 


3 Ductility of three pure irons at elevated temperatures

±3°C. One end of the specimen was permitted to move freely in an axial direction so that during torsional testing the specimen could become shorter or longer. Depending on the temperature range both shortening and lengthening of the twisted specimens took place.

Torsional strain is defined as the distance moved, under an applied torque, by a reference point on the surface of the specimen divided by the original gauge length. Thus the torsional strain is equal to  $\pi D/\text{Lo} \times N$  where N=the number of twists, D=gauge diameter, and Lo=original gauge length of specimen. For the specimens used in this investigation, the torsional strain per twist is 62.8%. A constant strain rate of about 47%/s (45 rev/min) was used.

## Results

The three irons (listed in Table I) were evaluated for their torsional ductility in the temperature range 600–1200°C; these results are shown in Fig.3. It is felt that all the data represented by the closed-in symbols refer to materials of about a constant grain size; it will be noted, however, that the behaviour of the as-received unannealed materials is not vastly dissimilar (open symbols, Fig.3).

Figure 3 shows three features of interest. Firstly, as might be expected, the high purity electrolytic vacuum-cast iron is the most ductile at all temperatures; the relatively impure Armco ingot iron is the least ductile and Puron falls in between. Secondly, the role of temperature is to increase the ductility of iron in each crystal structure range, with the exception of a brittle region in the alpha range near the transformation temperature where the ductility decreases to a minimum. Thirdly, extrapolation of the 600–800°C alpha iron data to the transition temperature indicates that alpha iron is considerably more ductile than gamma iron.

# DISCUSSION

The factors affecting the ductile fracturing of pure metals at high temperature have not been clearly established or separated. The following factors would be expected to contribute to an increase in the hot ductility: (a) increased number of slip mechanisms, (b) increased self-diffusion rate of atoms, (c) increased ease of twinning, (d) increased ease of grain boundary shearing, and (e) increased ease of recrystallization.

The number of active slip mechanisms is strongly dependent on the crystal structure. Body-centred-cubic (bcc) iron is believed to have 48 slip mechanisms;

these arise from six (110) planes with two directions of slip in each plane together with 12 (112) planes and 24 (123) planes with one slip direction in each plane. 19,20 Face-centred-cubic (fcc) iron, on the other hand, is believed to have only 12 slip mechanisms arising from four (111) planes each containing three slip directions. This consideration would favour higher ductility characteristics for alpha iron over gamma iron since many slip mechanisms would reduce the chance of inducing high internal stress regions at grain boundaries from dislocation pile-up. Locking of dislocations by foreign atoms, especially interstitials, would be expected to be unimportant at the high temperatures of testing used in this investigation because the diffusion rate of interstitials is extremely rapid.

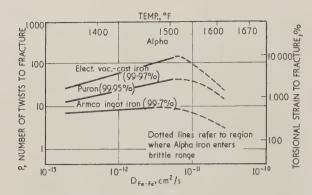
The rate of self-diffusion is also strongly dependent on crystal structure. Body-centred-cubic metals invariably exhibit a much more rapid rate of diffusion than metals crystallizing in the close-packed fcc or hexagonal close-packed structures (compared at same ratio of absolute melting temperature). This is due to the more open looser packed bcc structure. Iron is no exception and Fig.1 clearly reveals that the diffusion coefficient of alpha iron is about 400 times greater than the diffusion coefficient of gamma iron at the transition temperature. An increase in the diffusion rate would be expected to increase the ductility of materials because of stress relief at dislocation pile-ups by dislocation climb. Again, from this factor alpha iron would be expected to be more ductile than gamma iron.

Deformation twinning may be affected by crystal structure; it is generally believed that bec metals twin more readily than fcc metals. Twinning, however, is probably an unimportant mechanism of deformation at high temperatures.

Grain boundary shearing and recrystallization may be affected by crystal structure but the influence would be expected to act indirectly; that is, the amount of grain boundary shearing and the recrystallization kinetics may be dependent on the atomic mobility and possibly on the ease of crystal slip in the material which in turn are dependent on the crystal structure. A more important factor affecting the ease of grain boundary shearing or recrystallization would arise from the presence of insoluble impurities. It has been shown, for example, that the presence of insoluble Fe in Al can almost completely prevent grain boundary shearing.<sup>21</sup>

# Role of purity on ductility

Perhaps the effect of purity on the ease of grain boundary shearing accounts for the differences in ductility at constant temperature for the three irons investigated. From the chemical compositions listed in Table I, it is rather evident that the amount of insoluble impurities such as sulphur decreases from Armco iron to Puron and is the lowest for vacuum-cast electrolytic iron. Two papers on sulphur distribution in alpha iron were recently published by Ainslie et al. 22, 23 These investigators showed that sulphur segregation at alpha-iron grain boundaries was much greater than could be explained by preferential grain boundary diffusion. This abnormal effect can be explained if it is assumed that sulphur is absorbed by dislocations in the boundary network; in fact, it was shown that the average density of dislocations in the



4 Role of atomic diffusivity on the ductility of three pure irons in the alpha phase

boundaries of the material was about  $10^{11}$  lines/cm<sup>2</sup> which is typical of values observed for a severely cold-worked material. Sulphur segregation and the resulting sulphur-dislocation network could substantially hinder grain boundary shearing and especially grain boundary migration. The latter is probably an important and necessary condition for continued grain boundary shearing.

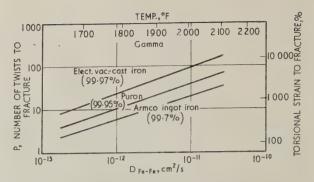
Continuous recrystallization during deformation may also contribute to high ductility at elevated temperatures. Gueussier and Castro<sup>16</sup> believe this is a major factor in determining the hot ductility of ferrous materials. It is difficult to determine quantitatively the degree of recrystallization in a material after hot deformation. This is because the presence of equiaxial grains after high temperature deformation can equally well be attributed to 100% grain boundary shearing. Current metallographic studies of iron deformed at 800°C do not reveal clear-cut evidence of recrystallization but have revealed the presence of considerable subgrain formation and grain boundary shearing.

# Role of temperature on ductility

It is evident from Fig.3 that the effect of temperature in general is to increase the ductility in the alpha and gamma phases of iron. A major contributing factor to this strong effect of temperature can possibly be attributed to the increased rate of atomic diffusion with temperature (Fig.1). It is therefore reasonable to plot the ductility, P (for plasticity) as a function of the self-diffusivity, D, and the results are shown in Figs.4 and 5. It is of interest to note that there appears to be a linear relation between logarithm P and logarithm D. In fact the slopes for the two purest irons (as well as for Armco iron in the gamma range) very nearly equal one-half. This suggests that the role of atomic diffusivity on ductility can be written as follows:

$$P\!=\!KD^{\frac{1}{2}}\!f(x)\ .....(1)$$

where K=constant and (f)x=function of other factors not yet defined. The term D½ may possibly be justifiable on theoretical grounds. Self-diffusion in iron is believed to occur by an atom-vacancy exchange process²⁴ in which case D is given by Doe-Qf/RT e-Qm/RT. Do is the diffusion coefficient about equal to 1 cm²/sec, Qf=energy of formation of a vacancy, Qm=energy of motion of a vacancy, R=gas constant, and T=absolute temperature. During extensive deformation as in ductility studies the term (e-Qf/RT)



5 Role of atomic diffusivity on the ductility of three pure irons in the gamma phase

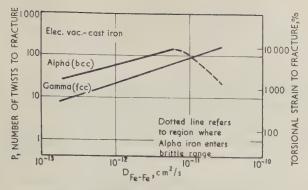
which is related to the number of thermal equilibrium vacancies present is probably not important because many more vacancies might be expected to be generated by mechanical means (dislocation intersection processes). The ductility would then be a function only of the energy for motion of vacancies, that is,  $P=Ke^{-Qm/RT}$ . This is now directly obtainable from the equilibrium diffusion equation  $D=Doe^{-Qf/RT}e^{-Qm/RT}$ ; it is generally agreed that Qf about equals  $Qm^{25}$  so that D can be written as  $Doe^{-2Qm/RT}$ . The square root of this expression as dictated by equation (1) yields  $Ke^{-Qm/RT}$  which is in agreement with the theoretical discussion.

It should be added that the increased rate of diffusion as a function of temperature would be expected to assist the ease of grain boundary shearing and especially grain boundary migration which would also be conducive to greater ductility.

The brittle zone in the alpha region (about 820° to 900°C) has sometimes been termed the 'hot short' region. It has been attributed by some investigators to melting of impurities such as sulphides at the grain boundary. On the other hand, it may be attributable to the formation of some gamma phase at the grain boundaries which may inhibit grain boundary shearing.

# Effect of crystal structure on ductility

It has already been indicated that alpha iron (excluding the brittle region) is considerably more ductile than gamma iron at the transition temperature. As mentioned earlier at least two factors have to be taken into consideration to separate the effects of crystal structure on ductility. Firstly, the self-diffusivity of atoms in the two structures is different (Fig.1), and secondly the number of slip mechanisms are different. To separate these two effects it is necessary to compare the ductility of alpha and gamma iron at the same constant rate of self-diffusion. This is effected in Fig.6 where the ductility is plotted as a function of D for the two crystal structures in the case of the purest iron tested. As is evident, bcc iron is more ductile than fcc iron and this difference in ductility can probably be attributed to the difference in the number of slip mechanisms between the two structures. There appears to be about a three-fold increase in ductility from fee to bee iron which almost agrees with the fourfold increase in number of slip mechanisms (from 12 to 48). Similar trends were obtained with the other irons studied although because of the slope differences



6 Comparison of the ductility of alpha and gamma iron at the same atomic diffusivity

in Armco iron in the alpha and gamma phases, inversions take place at high values of the diffusivity.

These results suggest that

$$P = SD^{\frac{1}{2}}f(x)$$
 .....(2)

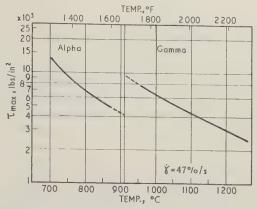
where S is about equal to the number of active slip mechanisms in the material.

Taking the electrolytic iron data only, the extrapolated duetility of alpha iron is about 100 times that of gamma iron at the transition temperature (on a logarithmic basis,  $2 \cdot 0$ ); the slip mechanism factor contributes to increasing the duetility of bcc by three times (logarithmic basis,  $0 \cdot 5$ ). It would appear, therefore, on a logarithmic basis, that about 75% of the difference in duetility of bcc and fcc iron can be attributed to a difference in atomic diffusivity and 25% to a difference in the number of slip mechanisms.

It must be emphasized that f(x) in equation (2) has been far from evaluated. It has been already clearly indicated that purity is one important factor; its role on the ease of grain boundary shearing, grain boundary migration, and recrystallization must be evaluated in order to better understand the factors affecting ductility.

Only one strain rate was used in this investigation; undoubtedly this variable would affect the degree of grain boundary shearing. In addition, at extremely high strain rates it is possible that diffusion processes would not have time to occur before the material fractured. In this manner it might be again possible to separate the diffusion effects from the crystal structure effects on ductility. Current studies are being made on the role of strain rates above 2000%s on the ductility of pure irons.

Hot rolling of steel is usually done high in the gamma range of temperatures (1200°C or higher). The results obtained in this investigation suggest that hot rolling or forging of low-carbon steels might be more profitably performed high in the alpha range of temperatures for the following reasons. (a) Alpha iron is inherently more ductile, hence it can be reduced more severely in one pass in contrast to gamma iron. (b) Lower heating costs and slower cooling rates would result. (c) Alpha iron is not only inherently more ductile than gamma iron but it is also inherently weaker because the faster diffusion rate in bcc iron accelerates the rate of dislocation climb and results in a weaker material. This difference in strength behaviour is clearly revealed in Fig.7, where the torsional strength of Armco ingot iron at constant strain rate is plotted



7 Maximum torsional stress of Armco ingot iron at elevated temperature

for the alpha and gamma phases. (d) The opportunity exists for development of any desired degree of substructure in the alpha phase which will be retained on further cooling. This would not be true in the case of hot working gamma iron. Such a situation in alpha working may yield better controlled values of tensile and yield strengths, modulus of elasticity, low-temperature ductility properties, and impact strength.

## CONCLUSIONS

The following pure irons were tested for their torsional ductility in the alpha and gamma ranges of temperature (600–1200°C) at a constant strain rate of 47%/s: (i) electrolytic vacuum-cast iron of 99·97% purity, (ii) Puron of 99·95% purity, and (iii) Armco ingot iron of 99·7% purity.

The duetility of these irons is directly a function of purity at all temperatures wherein the purest iron shows the greatest duetility.

The role of temperature is to increase the ductility of iron in each crystal structure range with the exception of a brittle region in the alpha range near the transformation temperature. This low ductility region might be attributed to impurity effects or to a premature formation of gamma phase at the grain boundaries preventing grain boundary shearing.

Extrapolation of the 600–800°C alpha iron data to the transition temperature indicates that alpha iron is considerably more ductile than gamma iron. Two factors appear to contribute to its increased ductility. The major factor is associated with the more rapid rate of diffusion of atoms in the open bcc structure and the second factor is associated with the larger number of slip mechanisms (48) in bcc iron in contrast to 12 slip mechanisms in fcc iron.

The results obtained suggest that the rolling of low carbon steels and commercially pure irons should be performed in the alpha range of temperatures (600–800°C) rather than in the gamma range. Not only is the ductility high for alpha iron but its resistance to deformation is low. In addition, refinement of the grains by formation of subgrains in the temperature range 600–800°C would probably result in a more uniform and stronger structure.

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# Recent and forthcoming Special Reports

# Steels for reactor pressure circuits

Special Report 69, which was published in August, contains the 26 papers and six discussion sessions of the symposium on steels for reactor pressure circuits, which was organized by The Iron and Steel Institute for the British Nuclear Energy Conference, and took place in London at the end of last year. Sir Leonard Owen's introductory address (which was reprinted in the September issue of the Journal) is followed by papers and discussions in five general groups: high-temperature properties, corrosion, fabrication aspects, irradiation effects, and steels for future reactors, and the report ends with a general discussion.

In octavo format, with 587 pages of text and extensive illustrations in line and tone, the report is priced at 65s (postage included) and is available from the Secretary of The Iron and Steel Institute.

# Structural processes in creep

It is hoped to publish towards the end of this year the papers and discussions presented at the joint meeting of The Iron and Steel Institute and The Institute of Metals in London, May 1961. This will be no.70 in the Institute's Special Report series, and full details will be given later.

# A computer and a melting shop

P. Beynon

## INTRODUCTION

ANYONE CONSIDERING the problem of using a computer for production control in a steelworks is soon faced with the decision whether to tackle the problem department by department or to consider the works as a whole. The second, though undoubtedly the more scientific method, is a massive and time-consuming task, which may be too large to envisage and which in any event may result in a solution whose cost may be exorbitant and which may be difficult to 'sell' to management because of the risk involved. The piecemeal approach, on the other hand, may serve not only to introduce management at all levels to the use of a computer without too much risk or cost but also to train and develop systems analysts and computer programmers at a practical rate.

The following is an example of the latter technique. It claims no great originality in method nor great economies in time but it does, it is hoped, show what

can be done in a rather complex case.

## THE DEPARTMENT

The melting shop to which this application has been made has seven OH fixed furnaces of 65 tons capacity, of which one is acid and six basic. This latter proportion is varied with varying commercial demands. The furnaces are cold-charged and gas-fired and they work a 20-shift week.

The output of the shop is divided between a tyre mill, a wheel mill, a heavy press shop, and a cogging mill, and as a result the ingots are of many shapes, sizes, and weights and many qualities of steel are produced, most of which are carbon steels with a small proportion of low-alloy steels.

The total output of the shop can reach about 5000 tons/week although the shop is now considered to

be inefficient and out-of-date.

The following types of ingots are available:

(i) 12-sided: 13in, 15in, 16in, 19in

(ii) octagonal: 25in, 30in, 32in, 37in, 40in, 48in, 54in, 63in

(iii) square: 20in.

# Scheduling

From a central production control department comes a requisition for ingots needed in the coming week. This is built up from the needs of the finishing departments for that week taking into account any limitations due to such factors as mould availability or slow-cooling facilities.

This requisition has to be converted into instruc-

Manuscript received 7 April 1961.
The author is with Steel, Peech and Tozer, Rotherham.

# SYNOPSIS

A computer is used for a recurrent task in a melting shop. Weekly ingot requisitions from a production control department are converted into instructions for all sections. The computer stores standards for qualities of steel and criteria of ingot grouping. When the requisition is fed in, it issues instructions on materials and method, the complete sequence being recorded on a teleprinter master sheet, which is reproduced in the form of cast cards. These cards are used for the programming of the shop and ultimately as a record of the cast for reference purposes.

1977

tions to all sections of the melting shop in sufficient time for all preparatory work to be completed.

It is this task which the computer undertakes.

#### Method

As with all computer applications the first stage in the program is to devise a series of standard methods for making every quality of steel.

This has involved for each quality:

- (i) deciding a standard mixture to be used
- (ii) assessing the melt carbon to be obtained
- (iii) deciding the additions to be made during refining
- (iv) deciding the finishings to be added
- (v) laying down, where possible, bath temperatures to be adhered to during refining.

It is appreciated that there is great difficulty in laying these facts down with certainty and that there is still much art in melting. Nevertheless it is felt that to control a process adequately one must start with standard instructions, measure the deviations from standard, and continually revise the standards in the

light of new knowledge gained.

These instructions are therefore worked out for each quality of steel and stored in the 'reference library' or 'memory' of the computer under a code number defining the quality. In the case of the pit-side, the main problem is to decide, when one cast is making several sizes of ingots, as in Fig.1, how these should be grouped. All the steels are teemed either uphill or tundished. Factors which the program takes into account are the optimum teeming rate, the total teeming time, and the maximum number of moulds that can be filled simultaneously. The grouping of ingots and the ladle nozzle used are connected, of course.

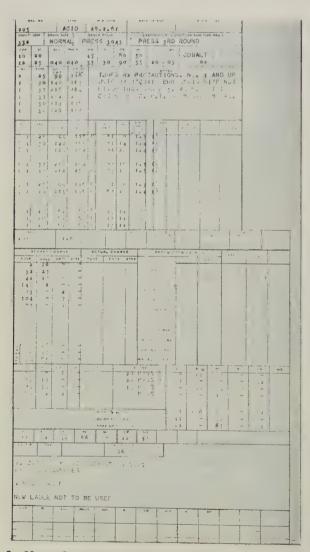
A method has been devised for arriving arithmetically at the best method of grouping ingots given all the

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1 Specimen sheet showing grouping of various sizes of ingot made at one cast. This sheet also illustrates a requisition for an acid cast

circumstances of the cast in both uphill and tundished casts. In the case of tundished casts the method takes account of the other known restrictions, such as that the discrepancy in heights between ingots within a group must be limited. It chooses a grouping, a teeming sequence, and a ladle nozzle. If the differences in flow rates for a particular group are large it then tries the effect of changing a single ingot or creating a further group.

Finally, the computer is made to produce a requisition for the different types of hollow-ware needed to produce the ingots requisitioned.



2 Master sheet corresponding to requisition shown in Fig.1

# TABLE I Main steps taken by computer

The specification of the cast is read from tape. This includes quality code, grain size, analysis, ingot requirements, and any notes referring to the cast



The program first calculates and outputs the pit details. These include the grouping of moulds, weights of ingots, chill lengths, tundish nozzle sizes, ladle nozzle size, and other details



The amount of pig iron and scrap to be charged are calculated



The program next calculates the finishings to be added, together with the times at which these should be added. On acid casts a chemical analysis of the finishings is also given



For basic casts, the desired melt carbon, refining temperature range, and tapping temperature are calculated For acid casts, the acid mixture analysis and the desired tapping temperature are calculated



The program also gives any special instructions, e.g. aluminium additions for fine grain casts, hydrogen samples to be taken



Details of refractories needed for the cast are given separately. This is used for the ordering of refractories in advance

#### **Procedure**

The requisition for each cast is typed on a master sheet on a teleprinter. Tape is produced simultaneously and this tape forms the input to the computer. Figure 1 is also an example of a requisition for an acid cast, and is self-explanatory.

The 'reference library' having been fed into the computer on a permanent tape, the current week's requisition is then fed into the machine. The output of the machine is a tape on which are married the requisition for each cast and the instructions for its manufacture. This tape is then fed into a teleprinter which produces a master sheet of which Fig.2 is the example corresponding to Fig.1. It will be seen that this master is designed in three main parts:

- (i) the top is a reproduction of the original requisition
- (ii) the middle is the instruction to the first on ingot grouping, nozzle sizes, etc.
- (iii) the bottom is the instruction to the stockyard and stage on materials to prepare and to the melter on the procedure for steelmaking.

In parentheses, it will be noted that for acid steels these instructions are given in much detail and are the result of much statistical analysis of the process. In this way, they differ from those for the basic process.

The master is produced in this way for two purposes. First, both the second and third parts can be reproduced as separate cards and given as instructions to the relevant sections. Second, the whole can be reproduced as a card showing the complete record of the cast for reference purposes. This card is also used for the programming of the shop, i.e. the allocation of casts to furnaces in such a way as to produce the casts at the required time.

Thus at one stroke all the necessary documents are produced in ample time so that instructions can be clearly and correctly given to all sections of the shop. Table I shows the main steps which the computer takes in doing this.

#### RESULTS

The result of this work is that what used to take a skilled and trained man  $2\frac{1}{2}$  days now takes  $\frac{3}{4}$  h computer time. This releases some skill for more useful work. It also ensures freedom from error and a constant approach to such problems as ingot grouping. In addition the need for defining standard procedures for all cases has compelled a complete review of practice, and the basis thereof, which has been of immense value. A further minor advantage has been an improvement in documentation.

The system clearly implies that all changes in practice will be reported so that they can be recorded in the 'reference library' of the computer. This is in any event a desirable procedure.

# **DEVELOPMENTS**

The above work is carried out on a Ferranti 'Pegasus' computer, which is available centrally, on a part-time basis. As the company operates a standard cost system it is clear that the data now processed should also be useful for evaluating standard costs. This step is in mind when the whole approach to computers is considered both from the production angle and the accountancy angle.

A piecemeal approach was advocated, rather mildly, at the beginning of this paper. Perhaps the reader, having read the last paragraph, will disagree.

## **ACKNOWLEDGMENT**

The author wishes to thank Messrs Steel, Peech and Tozer for permission to publish this account.

# STAL in English

Number 7 (July 1961) of the cover-to-cover translation of the Russian journal *Stal'* will be published shortly. Principal contents are given below. Full details of subscriptions to *Stal in English* are available from the Secretary of The Iron and Steel Institute.

# IRONMAKING

Updraught sintering

Removal of arsenic from Kerch ores in magnetic roasting Automatic control of blast-furnace slag granulating plant

## STEELMAKING

Heating ingot tops with exothermic mixtures

Exothermic mixtures and inserts for heating ingots

Hydrogen in steel

# **ELECTROMETALLURGY**

Electrical system in an 80-ton arc furnace Replacing ferrotungsten by concentrates at Chelyabinsk

# **FERROALLOYS**

Selecting self-baking electrode diameters for ferroalloy furnaces

# ROLLING AND TUBE PRODUCTION

Metal pressure on channel forming rolls Rolling channels on a 550 mill Calculating contact surface during piercing Steel cylinder manufacture in England Groove pass checker for use in cold rolling

# METALWORKING AND HEAT TREATMENT

Effect of heating slabs on electromagnetic properties of transformer strip

Effect of annealing conditions on the properties of high-speed steel

Effect of vacuum casting on the quality of heavy forgings

Rolling heat for the annealing of steel

Effect of heat-treatment temperature on the susceptibility of 1Kh18N9T tubes to intercrystalline corrosion

# **ECONOMICS AND ORGANIZATION**

Allowance for iron from the ore in an open hearth furnace charge

Reducing the labour costs of sinter production

# **HEAT TECHNOLOGY**

Increasing the capacity of a continuous furnace with a wide, sloping, monolithic hearth

# SMALL COMPONENT PRODUCTION

Efficient cross-sections for shaped wires for full-lock coil ropes

# FOUNDRY PRACTICE

Mould service at the Magnetogorsk combine

Journal of The Iron and Steel Institute October 1961

# Discussion at the Annual General Meeting 1961

The Annual General Meeting of The Iron and Steel Institute was held on Wednesday and Thursday, 3 and 4 May 1961, at the Institution of Mechanical Engineers, 1 Birdcage Walk, London SW1. At the technical session on oxygen steelmaking, held on 3 May, the President (Sir Charles Goodeve), was in the Chair. The papers presented have already been published in the Journal.

# Discussion on oxygen steelmaking

This discussion was based on the following papers (dates of publication in the *Journal* are given in parentheses):

'The pre-refining of blast-furnace iron and development of the Brymbo oxygen/electric steelmaking process', by E. Davies (Brymbo Steel Works) (1961, 197, April, 271-282)

'Operation of the oxygen/steam blown converters at the VLN steelplant of The Steel Company of Wales Ltd', by M. C. Harrison and P. Truscott (The Steel Company of Wales Ltd) (1961, 198, Aug., 341-352).

Mr Harrison and Mr Davies presented the papers.

Mr A. Jackson (The United Steel Cos Ltd): I should first like to congratulate Mr Emrys Davies and to say how pleased I am that the Institute recognized his work by awarding him the Hadfield Medal.

It has been suggested that among the new oxygen processes there are some which he could have installed with greater advantage than the one he has invented. One could, however, discuss possible alternatives at length without finding one which is especially applicable to his operations. Thus, a process had to be designed to suit the particular local circumstances prevailing, and this is just what Mr Davies has done. He has built a furnace with essentially a low refractory and capital cost, and a very high availability. It does the work he requires efficiently; the heat losses from not consuming the carbonmonoxide will not be high because quite a lot of the carbon is retained by the metal when it is taken away to the furnace. In spite of all other considerations, it would be very difficult to find a process more suitable than the one he has invented for this particular job.

There are a few questions of detail that I should like to ask. First, how far is the lance below the metal surface? Is it below the metal surface all the time, or is it sometimes immersed or on the surface? When lancing, does some of the metal and slag which is thrown upwards, fall back on the lance stalk itself, or is the splashing projected at an angle almost equal to that at which the lance is inserted? Also, what does Mr Davies mean by a thermostatically controlled lance?

Finally, what proposals does he have, if any, for using both the heat of combustion and the sensible heat of the gas that leaves his furnace?

In the second paper, the authors state that, having decided to have some type of pneumatic process, because of the low capital and conversion costs inherent therein, the oxygen/steam process was decided upon for various reasons. They proceed to give three reasons: the favourable supply of ore, that OH furnaces can use all the available scrap, and the steel required, in particular the very low level of nitrogen attainable.

Reading these comments in the light of present day knowledge, one imagines that the process has been selected in preference to LDAC, KALDO, etc., and one wonders whether this really is justified. For the oxygen/steam process to be operated in 1959, it is clear that someone had to decide probably in 1956, or even before, that this particular process was going to be installed, and, reflecting on 1955 and 1956, I can remember the experts saying that the LD would not take anything above 0.5%P. If they had to make a decision now, I wonder whether the authors would still install the same process.

Having decided to use the oxygen/steam process, I am sure that the company should be congratulated for their courage in dispensing with a separate air-blowing plant.

A large amount of interesting information has been given; however, there are a few questions that I should like to ask. First, concerning the slag volume; if one calculates this from information given in the paper, it appears to be of the order of  $5\frac{1}{2}$ - $6\frac{1}{2}$  cwt/ton of ingot. Is that so, and how much is high-phosphorus and how much low-phosphorus tapping slags? Again, based on the paper, one may assume that the bottom dolomite is 15-20 lb/ton. It appears that the dolomite for the whole process may be approaching 60 lb. Also, how many inches per ton of copper tube were used in making the bottom?

In recent practice a mixture containing 60% oxygen is used for the major part of blowing. As the plant appears to have no fume cleaning arrangements, at what level of oxygen concentration will fume emission become prohibitive under present-day factory regulations?

Finally, the paper makes no reference to cooling with ore. Is ore used for cooling? If not, it would be interesting to hear the reason.

Dr W. S. Walker (Campbell, Gifford and Morton): I think it is incumbent upon all of us to pay a tribute to Mr Davies and his colleagues for their pioneering efforts in the introduction of this new steelmaking process to our industry.

I only wonder whether the electric furnace is an essential part of the process, and whether excellent steel could not be made in the refining vessel. It would be interesting to know whether this is possible.

I should like to ask Mr Davies whether he has a heat balance for a typical charge made by his process, and whether he has compared this with the heat balance of a similar charge made either by conventional cold metal practice or by conventional hot metal practice. It would be interesting to compare the results, and to see what the metallic yields are like in the three processes.

Mr **D. P. W. Gampbell** (Richard Thomas and Baldwins Ltd): More than one lance has been mentioned as having been used in the pre-refining vessel up to the present day. Initially two lances were used, these being discarded in favour of an Oberhausen lance. It would interest me greatly to have information on (a) water pressures used in the different lances, (b) water

flow rate in the different lances, and water velocity in the annulus, (c) were the first two lances thermostatically controlled?

Excessive erosion of the bath was caused using the two original lances. The inference in the paper is that by the use of the single Oberhausen lance this was prevented. Can some elaboration of this point be given?

One can expect that a certain amount of abrasion has been obtained in the lance due to the passage of the lime/limestone mixture. Can Mr Davies indicate the level of abrasion obtained, and whether or not any special precautions have been necessary?

Dr Ing. **H. Neuhaus** (Klöckner-Werke AG): I should like to congratulate The Steel Company of Wales on the successful work with the oxygen/steam VLN process.

After adapting the process from Continental practice, the company had to solve a lot of problems concerning the special conditions existing in Port Talbot. There was no installed airblower, and no workers with any experience in bottom blowing converter practice. All problems were solved in a short time and in the course of this they developed some extremely interesting improvements.

There are a few questions I should like to ask: Mr Harrison said in his paper that the temperature of slag was sometimes higher than that of steel. I think, in a bottom blowing process, that the temperature of the steel-bath and slag must always be the same because of the mixing effect of the blast.

It can be economically important to use more scrap in the oxygen/steam process. Therefore, the experimental work with the higher oxygen/ratio without marked decrease in bottom life is very interesting. The significant difference in the development of bath temperature may indeed promote some metallurgical reactions. However, one must allow much more brown fume during the early stage of the blowing time.

The oxygen contents in the liquid converter metal, presented in the paper are, in my opinion, only of theoretical metallurgical value. There is a considerable decrease of oxygen during boiling in the mould on a level corresponding to the carbon.

The N content of VLN quality is the lowest in all steel-making processes. I believe, that there is under the same conditions, a relationship between oxygen purity and the N content. The result is 0.001%N with 99.5% purity; on the Continent, 0.002–0.003%N with 97% purity is achieved. A similar relationship was found in the top blowing process, however in this case with a marked difference that for 97% purity, the N would increase to 0.005%, that is, to the OH level.

Although a 0·001%N content is the lowest in steelmaking processes, I think, it is possible to reduce it substantially by the application of open coil annealing. Perhaps, in this way we could estimate the lowest possible rate of ageing for rimming steel. This would establish significant advantages over other steel grades, arrived at by various steelmaking processes.

Because of the very low N, a resultant is the same mechanical properties as those in OH steel, even though the P content in VLN is higher. Possibly, the P content could be reduced a little more by decreasing the  $P_2O_5$  or increasing the CaO content, using a high proportion of lime powder, for the second slag. Thus, the iron losses would decrease and the yield increase.

Generally, by dephosphorization using two slags in the oxygen/steam process, the production of a reliably low P content at a tap time of 20–30 min for a 60-ton heat is possible.

Monsieur J. Daubersy (SA Métallurgique d'Espérance-Longdoz): The oxygen/steam process originated in the old basic Bessemer steelplants, where the vessel capacity was only 16 tons and the method of controlling and weighing was insufficient. However, in spite of these bad operating conditions, steel quality was good and the N level was the lowest it had ever been. The process was directly operated on an industrial scale to produce deep-drawing sheets.

At that stage, we thought that the application of the steam/ oxygen process to large modern vessels would give better results. An increase in the regularity and a better heat balance resulting in higher scrap input was hoped for. But it was just a theoretical view and we had no big converters to prove it.

The Steel Company of Wales was the first to build vessels of 60 tons capacity, blown with the oxygen/steam mixture, and to have the courage to operate without an air blower. They have done a very good job and must be congratulated for it.

The operation of the converters at SCOW as related by Harrison and Truscott has shown that:

- (i) the oxygen/steam process may be used with large modern vessels without excessive problems concerning the life of the bottom
- (ii) higher oxygen/steam ratio during the carbon blow allows the use of scrap inputs of 15%, without any marked bottom difficulties
- (iii) the life of the lining remains the same as with air blowing, the time of blowing being very short, as it is in smaller converters. This results in a very high productivity, the highest that it is possible to achieve in a steelplant
- (iv) the N content is consistently very low, averaging 1000%. The lowest level is obtained when the whole heat is blown with the oxygen/steam mixture
- (v) the quality of the steel for drawing application is equivalent, just after skin pass, to a good OH steel; but the very low N level gives a reduced rate of ageing.

It is evident that blowing with pure oxygen without steam presents higher possibilities for scrap melting. But oxygen/steam blowing is not to be neglected for it results in a high quality and regularity for drawing purposes. With continuous casting, high productivity and the very short and consistently regular time of blowing make that process the most attractive to operate.

Dr A. J. Kesterton (The Steel Company of Wales Ltd): I should like to congratulate Mr Davies on his pioneering work in developing the oxygen refining process for hot metal. I should also like to ask two questions. The refining cycle takes about 1 h, and in the example given charging commences at 6.05 pm with 2 tons of scrap, followed by 20 tons of hot metal 15 min later. Does the refining cycle need to take 1 h? What operation is being carried out between 6.05 pm and 6.20 pm?

Mr Davies has stated that the increased production rate reduces the overall cost per ton of steel by spreading the fixed charges, and reducing the operating costs of electrodes, electricity, etc. Is the overall steelmaking cost lower with this process than when using 100% scrap charges? Do the financial savings counterbalance the difference in cost between scrap and hot metal, which is a considerable one, and to which is added the operational cost of the refiner and the fact that the yield of refined iron is about 93%?

I must congratulate Mr Davies on the original idea of using lime for fettling, which is evidently quite satisfactory in a refining furnace. I do not imagine that it would be satisfactory in a steelmaking operation where the temperatures are higher, but I should like to hear his opinion on this.

Referring to the VLN process, I would like to make one further observation. Its most significant feature is that the nitrogen reaches uniquely low levels. The reasons for this are interesting, and are probably as follows. The blast has an extremely low partial pressure of nitrogen, lower than is achievable in any other steelmaking process, since it consists of about 50%O, which contains a maximum of only 0.5%N, while the steam contains none at all. The LD and top-blowing processes use oxygen only, and therefore they must have twice the partial pressure of the nitrogen in the blast.

The other important point is that the volume of flushing gas is effectively doubled, compared with the top-blown oxygen processes. The volume of carbon-monoxide produced is common to both, but the steam over the whole length of the blow in effect doubles the quantity of flushing gas.

The third advantage is that at the point of impact of the oxygen on the metal, in the top blown process, a very high temperature must arise in the reaction zone, which will cause some nitrogen pick-up even from the low nitrogen concentrations in the oxygen. At the equivalent point of contact in the steam/oxygen process, which is as the blast emerges from the tuyeres, the steam lowers the reaction zone temperature and inhibits the nitrogen pick-up.

I think those are the reasons why this process has a uniquely low nitrogen content which, as has been pointed out by Mr Harrison, is of supreme importance from the point of view of steel sheet required for deep-drawing applications.

## **AUTHORS' REPLIES**

Mr Harrison, in reply: With regard to Mr Jackson's questions, if high-phosphorus iron is to be used I do not think there is any question but that we would make the same decision now as when this plant was designed. If one considers the operation of the VLN plant as against using low-phosphorus iron in the LD, obviously the LD has one big advantage operationally in that it has no bottom changing. On the other hand, the LD lining life is not so good. I would not say that the phosphorus analysis, unless you have a very low-phosphorus iron, is any better. From the point of view of deep-drawing quality, both the carbon and the nitrogen in the LD would probably be a bit higher, and for that reason may not be so good. The blowing time of 10–12 min and overall cast-to-cast time of 30–35 min for steam/oxygen blowing is considerably faster than LD.

The slag volumes are about 25% of the metallic input, of this about 70% is of a very high  $P_2O_5$  content (18–21%). The overall dolomite consumption is 35–40 lb/ton; that includes the bottoms and the linings. With regard to the use of copper tube, there are 284 tuyeres in the bottom. Each tuyere weighs 1 lb. It is apparent how much we use. Copper in the finished steel is in the region of 0·03%.

No ore is required for cooling, the final tapping temperature can be controlled very closely by adjustment of the oxygen/steam ratio, about 75% of the casts are within  $10^{\circ}$  of the figure aimed at. That is another aspect in which I think this process has a big advantage over the LD.

With regard to Dr Neuhaus's comments, I would say that, so far as we are concerned, there is definitely a difference between the temperature of the slag and the metal. This is accentuated by using over-burnt lime. The very low nitrogen is an established fact. The only time when we see high nitrogens, perhaps up to 0.002% is in making special steels where two or three ladles are used, in tipping one ladle into another there is a pick up of nitrogen. The actual level in the pit sample is affected by the purity of oxygen blown.

Dr Neuhaus is perhaps right in saying that an increase in the fine lime added for the second blow might give a reduced phosphorus. It would, however, result in a longer blowing time and decreased ingot yield, as well as increasing the lime consumption/ton of steel.

Mr Davies, in reply: Mr Jackson asked about the positioning of the lance. We emphasize the need for using a surface lance before immersing the main lance, and there is unquestionably immersion to a depth of 6-9in below the surface. The reason for that must be obvious. As I mentioned in my paper, you have the choice of either blasting at high velocity and splashing the slag and steel all over the vessel and sometimes through the top, or of blowing it in with low pressure. It is better to blow at low pressure below the surface, provided that you have sufficient turbulence. I feel that this is the better way so far as oxygen efficiency and refractory life is concerned.

Let me clear up a misunderstanding regarding temperatures. We regularly operate this vessel at temperatures approaching 1600°C, which are not so greatly below that of the ordinary furnace temperature; but we do feel that blowing at low pressure is better than blasting at very high supersonic speeds from up above.

I think that what I have said in part answers the question

about splashing. It occurs in the first stage when the jet of the small lance is immediately above the slag surface, and that takes place for about 5 min until a good cover of slag is formed. Then the main HOAG lance is immersed.

With regard to thermostatic control, in our case it mean that at a given temperature, a warning bell rings and the lance is automatically retracted. It occasionally happens during the summer when the ambient temperature of the water is high.

There is no doubt that there is room for heat utilization, and that is something that I would go into. We are not big consumers of steam, and we are getting away from it. There is an enormous amount of CO (carbon monoxide), (up to 45%) blown during the beginning of the carbon reaction, and it could well be utilized.

# WRITTEN CONTRIBUTIONS

Mr Campbell wrote: I have two further questions on Mr Davies's paper.

It is stated that one nozzle has been in use in the Oberhausen lance for 964 heats. In view of the abrasion to be expected from the injection of the lime/limestone mixture, it would be interesting to know if this has been achieved without any repairs. If repairs, however, have been carried out, can information regarding these be provided?

Finally, the usefulness of the oil burner for keeping the slag open at the end of refining is mentioned and its effect on the Fe content of the slag was stated as being appreciable. Can some figures be produced to illustrate the drop in Fe which can be expected?

Mr C. A. Reed (Skinningrove Iron Co. Ltd) wrote: There are two points upon which I would be interested to have some information. First, with regard to refractory renewals, what is the length of time the pre-refining furnace is out of production (a) to renew the roof, (b) to renew the roof and lining, (c) to carry out a complete major repair including hearth renewals?

On pp.277–279 of Mr Davies's paper, I should like to know the depth to which the main water-cooled lance is immersed into the metal bath during blowing operations. Also, with reference to p.273, I agree with the author that the ladle is not a suitable vessel in which to carry out desiliconizing and dephosphorizing of blast-furnace iron. We at Skinningrove came to this conclusion in the few experiments we carried out in this connexion.

Mr Davies wrote in reply: Concerning the questions asked by Mr Campbell:

Lances The lances used before the adoption of the Oberhausen lance were those originally supplied with the vessel and also a number which we tried to develop ourselves. All these lances were fed from the works water main, were not thermostatically controlled, and all failed for a similar reason, the development of a hot spot on the body of the lance resulting in a burst through the casing.

The Oberhausen lance, which is the same as that used on the rotor, has been used under the temperature and pressure conditions laid down by the manufacturer: these conditions you will know from your own installation. This lance was purchased specifically for its ability to withstand submerged blowing, and therefore the conditions are very similar to those in the rotor. The lance body exists in all three phases during the blowing, i.e. the tip of the lance is in the metal phase, the end of the body is in the slag, and the remainder is surrounded by the burning waste gas. The precise temperature levels are difficult to estimate but there should be no doubt that the end of the lance is submerged in the metal during blowing.

All lances used before this one were fed directly from the works water main, the supply pressure being about 25 lb/in². The flow rate at this pressure was between 60 and 80 gal/min, depending on the lance size used.

I would stress that any departure from these conditions has resulted in lance failure.

Lance abrasion We have, so far, had no difficulties due to

internal lance abrasion from lime dispensing nor has any damage occurred in the nozzle or lance tube.

Bath erosion The major cause of erosion came from the lance which passed tangentially through the back wall of the furnace, the oxygen stream being directed towards the bottom of the tapping slope. The Oberhausen lance is, in fact, in the same position as the original axial lance, it being possible to tilt the furnace during blowing. It is interesting to note that we are

now using two lances as originally planned to achieve the oxygen input rate of 1600 ft<sup>3</sup>/min which was the original design figure. The second lance is a surface blowing portable water-cooled lance of our own design.

Oil burners The effectiveness of the oil burners in reducing the Fe in the slag after the completion of the blow has been shown by continuous sampling. It has been found that a reduction of some 4% occurs in about 5 min.

# The British Nuclear Energy Conference

#### Contents of the Journal 1961

The Journal of the British Nuclear Energy Conference is published four times a year: in January, April, July, and October. It consists of papers and discussions on the applications of nuclear energy and ancillary subjects.

The July issue included the papers in the Dounreay fast reactor symposium and a paper on pressure vessels for gas-cooled graphite-moderated reactors. The October issue will contain all the papers in the symposium on secondary surfaces for heat transfer.

The annual subscription is £1 10s for members of The Iron and Steel Institute and The Institute of Metals, as well as the following societies: The Institution of Civil Engineers, The Institution of Mechanical Engineers, The Institution of Electrical Engineers, The Institute of Physics and the Physical Society, The Institution of Chemical Engineers, The Institute of Fuel, and The Joint Panel on Nuclear Marine Propulsion. For all others the subscription is £3.

Requests for detailed information should be made to: The Secretary, BNEC, 1-7 Great George Street, London SW1.

# A note on comparative stress-corrosion behaviour of some high-alloy steels

We have studied Mr Snowden's interesting investigations\*concerning stress corrosion of stainless steels and are pleased to note that very good agreement exists with the results obtained in our own tests as shown in Tables 1-4.

The specimens were taken from hot-rolled normally annealed sheet (U-bend specimens) and bar steel (uniaxially loaded specimens) respectively. The U-bend specimens (15×150 mm) were bent over a mandrel with a radius of 7.5 mm and secured between 25 mm wide insulated clamps. The specimens for uniaxial loading tests (3 mm dia.) were annealed at 1050°C in argon gas protection, electrolytically polished and passivated in HNO3 after machining.

Tests at atmospheric pressure were carried out in a glass apparatus, while the tests at higher temperatures and pressures were made in titanium- or nickel-lined autoclaves. In both cases the specimens have been entirely submerged in the solutions.

# Micro-examination of specimens

The cracks caused by chlorides are transcrystalline in the austenitic and the ferritic-austenitic steels. In the last mentioned type of steel the cracks are running through the ferrite as well as the austenite.

TABLE 1 Typical analyses of material used, %

Quality	C	Si	Mn	$\operatorname{Cr}$	Ni	Mo	N	Ti	Cu
832 M	0.07	0.35	0.9	18.0	9.5		0.04		
832 SV	0.05	0.35	1.3	17.5	10.0	1.5	0.04		
832 SK	0.05	0.35	1.3	17.5	11.0	2.7	0.04		
$832~\mathrm{SKR}$	0.03	0.35	1.3	17.5	11.5	2.7	0.04		
832 SKT	0.07	0.35	1.3	17.5	12.5	2.7	0.04	$5 \times C$	
832 SKE	0.05	0.35	1.3	17.5	14.0	2.7	0.04		
832 SL	0.05	0.35	1.3	17.5	14.5	4.5	0.04		
254 SKX	0.05	0.35	0.6	20.0	24.0	3.0	0.04	$5 \times C$	2.0
453 S	0.08	0.35	0.6	26.0	5.0	1.5	0.04		

TABLE 2 Uniaxially loaded specimens in chloride solutions

Quality		Cl <sub>2</sub> , 100°C,	specimens tested in $0.1\%\text{Cl}^-\text{(NaCl)}$ , $150^\circ\text{C}$ , $15~\text{kg/mm}^2$					
832 M 832 SV 832 SK 832 SKR 832 SKR	20 97 166 173 266		130					
832 SL 254 SKX	500 600	NC NC	500	NC				
453 S	1000	NC	500	NC				

NC=No cracks

Also the cracks occurring in NaOH solution are substantially of a transcrystalline nature but there are also branches following the grain boundaries.

S. Berg

S. HENRIKSSON

Avesta Jernverks Aktiebolag Avesta, Sweden

TABLE 3 U-bend specimens in chloride solutions: single tests

Cl-	Cation	Temp.,	Quali 832 M	832 SK	832 SKE	832 SKT	832 SL	453 S
5000	Na+	250	41.5	+	+	+	+	+
5000	Na+	150	+	+	+	+	+	+
500	Na+	250	÷	+	+	+	+	+
500	Na+	200	+	+	+	+	+	+
500	Na+	150	+	++	+	+	+	+
250	Na+	200	+	_	_	_	_	+
250	Na+	150	+	+	+	+	+	+
100 100	Na+	250	+	++	+	+	_	+ + + + + + + + + + + + + + + + + + + +
100	$\mathbb{K}^{+}$	200	+		+	_	-	+
100	Ca++	200	+	+	+	+	+	++++
100	Mg++	200	+	+	+	+	+	+
100	$\mathbf{K}^{+}$	150	+	+		+	+	
100	Na <sup>+</sup>	150	+	+	+	+		- + + +
100	Ca++	150	+	+	+	+	_	+
100	Mg++	150	+	+	+	+	+	+
50	NaT	250	+	+	+	+	+	+
50	Ca++	250	+	+	+	+		+
50	$\mathbf{K}^{+}$	200	+	+	+	+	+	+
50	Na <sup>+</sup>	200	+	+	+	+	+	+
50	Ca++	200	+	_	-	_		+
50	K+	150	+	+-	+	+	+	-
50	Na+	150	+	+		_	_	_
50	Ca++	150	+	+	+	+	_	
50	Mg++ K+ Na+	150	+	+	+	_	_	_
10	K+Na+							
	Ca++	no crack	s at 15	50, 200,	. 250, a	nd 300	$^{\circ}\mathrm{C}$	
	$M_{\sigma^{++}}$							

+ = cracks

—=no cracks in 10 days
No cracking occurred in 1000 ppm Cl<sup>-</sup>(NaCl) at 150°C in the presence of 500 ppm hydrazine hydrate.

TABLE 4 U-bend specimens in sodium hydroxide solutions: single tests

NaOH, %	Temp.,	Dura- tion of test, h	Qua 832 M	lity 832 SK	832 SKE	832 SKT	832 SL	453 S
10 20 25 25 30 30 30+500ppm hydra- zine hydrate	220 200 200 150 200 150 200	180 120 144 144 2 120 18	++++	- + + +	++	- - - +M	+++	- - +M

+ = cracks

=no cracks

M=micro-cracks only. All the other specimens are severely cracked.

<sup>\*</sup> P. P. SNOWDEN: JISI, 1961, 197, 136-141.

All results in Table 2 are average values of 2-10 tests.

# An appreciation of the late Professor J. H. Andrew

To all students and research scholars in metallurgy spread today the world over who have passed through the citadels of the University of Sheffield, the sad demise of the late Professor J. H. Andrew must have come as a personal loss. Speaking for those in India, whose professional destinies were moulded by the master hand and mind of Professor Andrew, it is indeed a grievous loss. To an Indian student landing on the icy and wintry shores of Britain for the first time, Professor Andrew's warm welcome extended in his own characteristic warmth, readily made up for all the lack of sunny weather left at home. My own association, both personal and professional, with Professor Andrew began during the Munich crisis of 1938 when I found myself for the first time in a new land throbbing with activity of war and peace. In that atmosphere of hope and fear, after I had spent my few hours with Professor Andrew, I knew I had landed home. Deep and varied have been our contacts extending over the last two decades; from his very sick-bed before he left this earth of minerals and metals, he replied to my letters with his unusual clarity of thought and balanced analyses on points both professional and personal.

Professor Andrew's career as a teacher of the science of metallurgy and as a research leader and guide has been one of the most distinguished and to my mind unequalled in some ways in its characteristic synthesis of the theory and practice of metallurgy – a synthesis which one not infrequently misses in many brilliant metallurgical careers. Again when I had the pleasure of meeting him in 1951 in the UK soon after his retirement to Llandudno, he mentioned to me his keen desire to write his memoirs on metallurgy wherein he so very much wished to postulate his experienced views on 'whither metallurgy'. His rapidly deteriorating health however, failed him. I personally feel with Professor Andrew's passing away, an era has also passed away in the realms of metallurgy. Professor Andrew's brilliant metallurgical career and research attainments are now being recounted in many metallurgical journals, and he is shown as one of the most distinguished metallurgists and teachers of metallurgy of his generation.

A graduate and later research fellow of the University of Manchester, he was head of the metallurgical research department of Sir Armstrong, Whitworth and Co. Ltd from 1914 to 1920, when he became professor of metallurgy at the Royal Technical College, Glasgow, from where Professor Andrew went to Sheffield on his appointment to the chair at Sheffield University and entered with enthusiasm into the not easy task of training future metallurgists. The responsible posts now occupied by his students in many countries of the world, are better evidence of his success than any words. Professor Andrew was one of those who insisted that, irrespective of whether one was ultimately to take up industrial or academic work, a training in research was a 'must' and an indispensable addition to a university course. Even though this advocacy was not then accepted with complete unanimity, today Professor Andrew's views are universally shared.

His research activities covered many virgin metallurgical fields, ranging in their depth as much as in scope. One of his very first papers dealt with the subject of nitrogen in steel and the relation between gases and metals, and in some of his latest and most successful work he returned to the same subject. Metallurgists in many lands are greatly indebted to him for the very excellent work which he did in trying to unravel the complexities of the relation between hydrogen and metals. His very interesting researches into work-hardening, grain size control of steel, and studies of alloy steels, won him in 1949 the highest award of The Iron and Steel Institute, the Bessemer Medal, in receiving which, Professor Andrew recounted that the success of a scientist depended partly on himself and more on those who assisted him, and that in his case he was indebted to more than 50 research workers whose names had figured with his in scores of research publications.

It will be hoped in many lands that the traditions he had succeeded in building up in the science and practice of metallurgy will be fully maintained and further strengthened.

B. R. NIJHAWAN

National Metallurgical Laboratory, Jamshedpur, India

 $(An\ obituary\ notice\ of\ Professor\ Andrew\ appeared\ in\ the\ August\ issue\ of\ the\ Journal.)$ 



# Shri D. L. Deshpande

Datta Laxman Deshpande, Director of the Bihar Institute of Technology, died on 5 April. He was born in 1909 and studied first at Bombay University where he took an honours degree in mathematics, and later at Manchester University where he gained his M.SC. in Engineering.

In 1932 Shri Deshpande returned to India where he joined the GBS Railway as assistant engineer. In 1935 he was appointed workshop superintendent and personal assistant to the locomotive superintendent. For the next two years he worked as a constructional engineer, and in 1939 he joined the College of Engineering in the state of Travencore-Cochin as professor of mechanical engineering. Shri Deshpande did much to raise the standard of teaching at this college so that it became one of the leading technical colleges in India. He was appointed principal of the college in 1943, a post he resigned in 1948 to become founder-principal of the Central Training Institute, Koni, Bilaspur. In September 1950 he was appointed Principal (later Director) of the Mechanical and Electrical Engineering College at Sindri, which has now become the Bihar Institute of Technology.

A man of great energy and many interests, Shri Deshpande did much to raise the standard of technological education in India. As a technical director he contributed his skill and experience to industry, and he served on many governing and technical committees.

Shri Deshpande joined The Iron and Steel Institute in 1957, and had many friends in this country and the USA who mourn his death.

# NEWS

# Announcements and News of Science and Industry

# THE IRON AND STEEL INSTITUTE

## Autumn General Meeting 1961

The Institute's Autumn General Meeting and the 43rd meeting of the Iron and Steel Engin-eers Group will be held in London from Wednesday 29 November to Friday 1 December **1961.** The programme was given on pp.77-78 of the September issue of the *Journal*.

### Special lectures

Lectures on 'The British steel industry and the Common Market' are being delivered by Mr C. R. Wheeler, C.B.E. (Past-President), President of the British Iron and Steel Federation, and His Excellency Dr E. N. van Kleffens, Head of the Delegation of the High Authority of the European Coal and Steel Community of the European Coar and Steel Community in the United Kingdom on the evening of Wednesday 29 November 1961 at the Hoare Memorial Hall, Church House, London SW1. Admission will be by ticket only, application forms for which will be circulated to Members.

# Annual General Meeting 1962

The Annual General Meeting will be held in London on Wednesday and Thursday, 2 and 3 May 1962. The annual dinner for members will be held on the Wednesday evening.

#### Special meeting in Germany, 1962

As previously announced, by invitation of the Verein deutscher Eisenhüttenleute the Insti-tute will hold a special meeting in Düsseldorf from Monday, 2 July to Sunday, 8 July 1962. The draft programme of the meeting is as follows:

Mon. Members and ladies arrive in 2 July Düsseldorf by train and aircraft Tue. 3 July

Members Opening session at Opera House Afternoon

Members Works visits in Düsseldorf area

Members and ladies Sightseeing tour of Düsseldorf

Evening Members and ladies Reception,

dinner, and dance, at the Rhein-terrasse, by invitation of the VdEh.

Morning Members Technical session at the Europapalast Afternoon

Members Works visits in Düsseldorf area with dinner Ladies Boat trip to Zons or Kaiserwerth

All day Thur. 5 July

Wed.

4 July

7 July

Members Works visits with lunch Ladies Visit to Blankenstein, Cologne, and Essen, with lunch Evening
Members and ladies Performance

at Opera House, Düsseldorf

All day Members Works visits, with lunch Ladies Visits to Krefeld, Troisdorf, or Leverkusen, or visits to Düsseldorf museums, with lunch

Evening free

All day Members and ladies Boat trip on Rhine by invitation of the VdEh

Sun. 8 July Return to UK by train and aircraft. or take part in special excursions (see helow) End of meeting

Special excursions

These will be arranged as follows:
No.1 Thursday 28 June – Monday 2 July
The Saar, Trier, and Aachen

No.2 Sunday 8 July -Heidelberg and Frankfurt 8 July - Monday 9 Julu

No.3 Sunday 8 July - Wednesday 11 July Hanover and Brunswick No.4 Sunday 8 July - Tuesday 10 July

Bremen and Hamburg.

### Special meeting in India 1963

The Council have accepted an invitation from the Indian Institute of Metals and the National Metallurgical Laboratory, Jamshedpur, to hold a Special Meeting in India in the early spring of 1963. The exact dates and programme have not yet been settled but it is probable that the meeting will start in Delhi during the last week in January, so that Members and Ladies may watch the 'National Day' celebrations on 26 January 1963. The main programme will last about a fortnight.

It is hoped that the programme will include a tour by special train visiting the steelworks at Durgapur, Bhilai, and Rourkela of Hindustan Steel Ltd and the plant at Burnpur of the Indian Iron and Steel Co. Ltd. Members and Ladies have been invited to visit Jamshedpur so that Members may take part in a joint sym-posium on 'Recent developments in iron and steelmaking with special reference to Indian conditions' organized by the National Metal-lurgical Laboratory. Visits will be arranged to this laboratory and to the Tata Iron and Steel Co. Ltd and other works. The meeting will conclude with a visit to Calcutta. Short sightseeing visits to other parts of India will be arranged to follow the main meeting.

# Joint meeting with the Institute of Fuel

As announced in the September issue of the Journal, a joint meeting with the Institute of Fuel has been arranged in London on Wednesday 13 February 1962 at the Institution of Civil Engineers, Great George Street, London SW1. The theme of the meeting will be 'Fuel and energy for various steelmaking processes', and the papers to be discussed are listed below. The date in parentheses refers to publication in

the Journal of the Institute of Fuel.

'Energy requirements of the Ajax steelmaking process', A. Jackson and S. H. Brooks
(Dec. 1960); 'Fuel and power required for
making steel in the LD process', Kurt Romer and Ferdinand Dobrowsky (Jan. 1961); 'Fuel and energy required for steelmaking by the VLN converter process, G. G. Fletcher and R. A. Pullen (Feb. 1961); 'Fuel and power required for making steel in the electric arc required for making sever in this electric act furnace', R. S. Howes and A. Jackson (March 1961); 'Fuel and energy required for steelmaking in the open-hearth furnace', R. Mayorcas and I. H. McGregor (April 1961); 'Fuel and energy required for the manufacture of the steel of th of steel by the Kaldo process', Folke Johansson and Bo Kalling (May 1961); 'Fuel and energy requirements for some possible future steelmelting processes', Professor M. W. Thring (July 1961). Sets of reprints of the papers will be available from The Iron and Steel Institute at a nominal cost; details will be announced

# Acta Metallurgica

Members are reminded that as the Institute is a co-operating society of Acta Metallurgica

certain publications of Acta Metallurgica may be obtained direct from the publishers at a reduced rate. This includes the book 'Contemporary problems of metallurgy', which will be reviewed in a forthcoming issue of the Journal.

# **NEWS OF MEMBERS**

Sir Douglas Bruce-Gardner, Bt., has been appointed to the board of Guest, Keen and Nettlefolds (South Wales) Ltd.

Mr J. G. Campbell has been appointed technical applications engineer with Morganite Carbon Ltd

Mr C. C. Hanson has left Radiation Ltd to join Chrome-Alloying Co. Ltd.

Mr H. A. Holden, manager of the metal finishing division of The Pyrene Company Ltd, has been appointed a divisional director of the

company.

Mr Gecil F. Hurst, deputy chairman of Samuel Osborn and Co. Ltd, has also been considered to the company of the company. appointed assistant managing director of the

Dr I. Jenkins is leaving the research laboratories of the General Electric Co. Ltd to take up an appointment as director of metallurgical research with the Manganese Bronze and Brass Group of Companies on 1 November 1961.

Mr C. M. Lyne has joined Jones and Laugh-lin Steel Corporation, Aliquippa, Pennsylvania,

Mr N. D. Macdonald has been appointed a director of Workington Iron and Steel Co.

Mr Mark Pearce has joined the board of Brymbo Steel Works Ltd.

Dipl.-Ing. F. Toussaint is assistant works manager of the Ruhrort works, Phönix-Rheinrohr AG

Mr B. Walker has been appointed research fellow in the Department of Industrial Metallurgy, Birmingham University.

Dr L. E. Webb has left Fulmer Research

Institute Ltd on his appointment as metal-lurgical process engineer to The Power Gas Corporation Ltd, Stockton-on-Tees.

## Obituary

Dr Ing. Rudolf Schmolke (elected 1958), of Oberhausen, on 21 June 1961.

# AFFILIATED LOCAL SOCIETIES

# MANCHESTER METALLURGICAL SOCIETY

# Discussion on metallurgical education

The Manchester Metallurgical Society is holding a general discussion under the title 'Education in the metallurgical field' on Wednesday 25 October at 6.30 pm in the rooms of the Manchester Literary and Philosophical Society, Manchester Literary and Philosophical Society, George Street, Manchester. Members of The Iron and Steel Institute, The Institute of Metals, and The Institution of Metallurgists are invited. The discussion will be introduced by L. W. Derry (Battersea College of Technology), Professor H. O'Neill (University of Swansea), and D. R. O. Thomas (The United Steel Companies Ltd).

# EBBW VALE METALLURGICAL SOCIETY

# Officers 1961-62

President F. W. Lewis; Vice-President W. E. Williams; Hon. Treasurer L. G. Hobbs; Joint Secretaries D. W. Evans and J. B. Davies; Members of Committee R. M. Bethel, T. E. Davies, W. Edney, P. T. Edwards, A. W. Ellis, I. Giddings, D. J. Jones, A. J. Meo, N. Morris, J. T. Mills, H. Padget, H. J. Powell, R. C. Powell, J. B. Thickins, E. T. Williams, and W. B. Williams.

# WEST OF SCOTLAND IRON AND STEEL INSTITUTE

# Officers 1961-62

President Dr R. Hunter; Vice-Presidents J. A. Kilby, G. S. T. Martin, J. M. Mowat; Hon. Secretary and Treasurer P. W. Thomas; Members of Council E. H. Baldwin, W. J. Cormack, Prof. E. C. Ellwood, J. G. Frith, D. Hadfield, I. G. Hamilton, W. I. Horton, I. M. Mackenzie, J. W. McWilliam, R. Malcolm, J. A. Russell, S. Senior, Dr J. Taylor, W. M. Service, R. P. Towndrow, J. W. Todd (ex officio); Hon. Members of Council (Past Presidents) W. Barr, Sir Andrew McCance, A. McKendrick, Dr H. Harris.

# BRITISH CONFERENCE ON AUTOMATION AND COMPUTATION

# Foreign relations panel

BCAC has set up a Foreign Relations Panel under the chairmanship of Mr J. F. Coales, O.B.E., M.A. Collaboration with international bodies working in the field of computation and automation, and sponsoring British contributions to international conferences will be among the functions to be undertaken by the new panel.

#### **IFIPS** Conference

The International Federation of Information Processing Societies (IFIPS), plans to hold a conference on computers from 27 August to 1 September, 1962 in Munich. Further information can be obtained from Professor M. V. Wilkes, University Mathematical Laboratory, Corn Exchange Street, Cambridge.

# **IFAC Congress 1963**

The International Federation of Automatic Control, at the invitation of the Swiss Association for Automatic Control, is to hold its second congress in Basle during September 1963. Submission of UK papers to the congress will be co-ordinated by a committee of the British Conference on Automation and Computation. The main topic will be the theory and application of automatic control, including the components of control devices. The final version of a paper offered by any UK author should reach the BCAC committee, the newlyformed Foreign Relations Panel, by not later than 1 June 1962, for transmission to the international selection committee of IFAC during the following August. The executive council of IFAC have ruled that the number of papers shall not exceed 100.

Offers of papers from the UK should be made to the Honorary Secretary, BCAC, c/o The Institution of Electrical Engineers, Savoy Place, London WC2. General enquiries regarding the congress arrangements should be made to the Secretary of IFAC, Dr-Ing. G. Ruppel, Prinz-Georg-Strasse 79, Düsseldorf, Germany.

# THE INSTITUTE OF WELDING

## Spring meeting and exhibition

In connexion with its spring meeting at Buxton, Derbyshire, from 30 April to 4 May 1962, the Institute of Welding is organizing its first large-scale exhibition 'Welding engineering 1962'. The exhibition in the Winter Gardens will include expanded versions of exhibits and demonstrations which have been featured in recent Institute meetings covering welding and allied processes and techniques.

The theme of the spring meeting is 'Welding for power generation'. Nearly 30 papers including several from abroad will be presented. The exhibition will illustrate the progress

of welding technology, with special emphasis on the challenge of modern power generation plant construction. Further details are available from the Institute of Welding (ref. Exhibition), 54 Princes Gate, London SW7.

# BRITISH WELDING RESEARCH ASSOCIATION

## Officers 1961-62

President Sir Charles S. Lillicrap, Chairman of Council A. Robert Jenkins; Honorary Treasurer W. E. Harriss; Members of Council Sir Donald Bailey, Professor J. F. Baker, D. J. W. Boag (Member), Dr T. W. F. Brown, C. H. Davy (Member), The Viscount Ednam, C. H. Flurscheim, E. J. Hill, F. C. S. Lewin-Harriss, Sir Andrew McCanee (Past-President), T. McIver, G. A. McMillan, Richard Miles, J. Mitchell, Professor Sir Alfred Pugsley, L. Rotherham, R. B. Shepheard, C. M. Spielman, T. Stevenson, J. H. N. Thompson, Lt.-Col. J. F. Todhunter, W. T. Towler, M. Muirhead Watson, Dr E. G. West, Harry West, J. M Willey.

Senior technical and administrative staff Director of Research, Dr R. Weck, Secretary, A. O'Neill, Deputy Director of Research, Metallurgy, H. F. Tremlett, Assistant Director of Research, Engineering, A. A. Wells.

# **EDUCATION**

# Gourses on design of cooling coils, and compact heat exchangers

The National College for Heating, Ventilating, Refrigeration, and Fan Engineering, at Borough Polytechnic, Borough Road, London SE1, has announced a series of lectures on 'Design and performance of cooling and dehumidifying coils', to be given on Tuesday evenings, beginning 24 October 1961. A course of six lectures on Monday evenings, beginning 23 October, is entitled 'Compact heat exchangers'. Details of both courses are available from Mr E. Woodcock, lecturer in heat transfer, at the college.

# Advanced courses in north of England

The Northern Advisory Council for Further Education has issued a booklet detailing special advanced courses in the north of England for the coming academic session. Copies are available from the secretary at 5 Grosvenor Villas, Grosvenor Road, Newcastle-upon-Tyne 2.

# AIM and LIM awards, 1961

The Registrar-Secretary of The Institution of Metallurgists has announced the results of the examination held last July at 14 centres in the UK and 12 abroad.

Associateship 142 of the 341 candidates examined passed, 119 were referred in one subject, the remainder failed.

Licentiateship 196 of the 731 candidates examined passed, 132 were referred, the remainder failed.

Pass lists have been distributed to colleges and examination centres and they were published in full in the September issue of *The Metalluraist*.

# National Council for Technological Awards: annual report

The report for April 1960–March 1961 shows a considerable increase in enrolments for the diploma in technology, and in registrations for membership of the College of Technologists. Nearly 5 000 students are taking courses in the diploma in technology, and more than 17 500 students of both sexes have enrolled in first-year courses. The council pay tribute to the enthusiasm with which colleges and industry in general have 'embraced the concept of the diploma in technology'.

A revised memorandum on awards conferred by the council is available from the secretary, National Council for Technological Awards, 9 Cavendish Square, London W1.

# NEWS OF SCIENCE AND INDUSTRY

# **New international corporation**

A new corporation to provide research, technical information, investment advisory, and management services in the USA and Europe is being organized with business associates by Dr Clyde Williams of Columbus, Ohio, USA. It will be known as the Clyde Williams Corporation and its main offices will be at 50 West Gay Street, Columbus, with branch offices in London and Paris. Among the officers of the corporation will be: President Dr F. R. Henzel, Chairman Dr Williams, Executive Vice-Presidents Dr H. E. Z. Gordon (London) and Dr L. K. Herndon. A main purpose of the company will be to provide liaison between European and US technology. Dr Williams established the laboratories of the Battelle Institute in Frankfurt and Geneva.

# Company news

The Steel Company of Wales Ltd is supplying regular shipments of timplate to the west coast of the USA for use in food canneries. By the end of this year more than 11000 tons, mostly in coil, will have been sent.

Elliott Brothers (London) Ltd has formed an automation analysis department within its data processing group of divisions. The new department is to be concerned with the true mathematical nature of industrial processes.

Head Wrightson Machine Company is to supply an Armeo Sendzimir continuous hot dip galvanizing plant to the Abbey Works of The Steel Company of Wales Ltd at a cost of £4 m.

Carblox Ltd are lining the first Greek blastfurnace being built near Athens.

Nitrogen shrinking in assembling heavy machine components has been applied successfully at Bayliss, Jones and Bayliss Ltd, Wolverhampton. In conjunction with British Oxygen, who supply the liquid nitrogen used for the process, two test shrinkings were carried out before the process was applied to an actual production job. Considerable savings in time and money are claimed for this method as an alternative to expanding components in a reheating furnace.

Allen West and Co. Ltd of Brighton have acquired the manufacturing interests of the Digital Engineering Co. Ltd, Battersea. Digital Engineering will operate as a subsidiary of the main company from its present offices and works there. Dr L. N. Bramley (Member), who has been managing director of the company since its inception in 1956, took up a full-time appointment in the same capacity on 1 September, and Mr W. N. Jenkins (Member), the other original director, is retained as a consultant. Mr G. H. Cann, M.B.E., F.C.A., is the chairman of Digital Engineering.

Birwelco Ltd, of the GKN group, have been licensed by Calderon Automation Inc., of Cleveland, Ohio, USA, to manufacture and sell Calderon scrap-charging equipment for steelworks throughout the UK and Commonwealth

Samuel Fox and Co. Ltd, a branch of The United Steel Companies, have started commercial production of Esshete 1250, a new alloy steel designed for service temperatures up to 675°C. It is a 15–10–6 Cr–Ni–Mn steel which includes smaller percentages of Si, Mo, V, Nb, and B. The result of five years research and testing, the new steel is claimed to have a high level of rupture strength with adequate ductility, good weldability, structural stability, and oxidation resistance at elevated temperatures for long periods, and is said to have good manipulation properties.

# Wellman group expand

Owing to expansion of activities, The Wellman Smith Owen Engineering Corporation Ltd have segregated their divisions dealing with cranes and mechanical handling equipment and rolling mill equipment and established them as subsidiary companies under the titles of Wellman Crane and Machine Co. Ltd, and Wellman Rolling Mills Ltd. The new companies will operate from the same address as the parent company, at Parnell House, Wilton Road, London SW1.

#### More Shell films

The two latest productions of the Shell Film Unit were recently shown in London. 'A question of springing' combines cartoon and documentary treatment to show briefly but clearly the development of suspension systems from the solid axle to the latest pneumatic-hydraulic combinations. The film is in colour, 35 and

16 mm, and runs for 18 min.

'The free piston engine' shows the remarkable development of an engine that derives from the basic principles of the two-stroke diesel and the gas turbine. The high efficiency and comparative simplicity of the free piston engine is obvious from the film, which again uses animation as well as direct photography. An excellent sound track, particularly in the cartoon sequences, makes this an extra-ordinarily effective film both as instruction and entertainment. Specifications are as for the previous film.

Both films are available on free loan from the film library of Shell-Mex and BP at Shell-Mex House, Strand, London WC2, who can supply a catalogue of all their available films.

# New Vickers works in Australia

At a cost of more than £1 m., Vickers Ltd are to build a heavy engineering works at Port Kembla, New South Wales, near the steel-works of Australian Iron and Steel Ltd. The new works will manufacture a wide range of plant and equipment for local requirements.

### Contract news

Davy and United Engineering Co. Ltd have received an order from Shelton Iron and Steel Ltd to supply Kaldo furnace plant for their Etruria works. The contract is worth about £1 m

Birlec-Efco (Melting) Ltd are to supply two electric-are furnaces for the Tinsley Park works of The English Steel Corp. Ltd, and for one similar furnace for the Hallside works of Clyde Alloy Steel Works Ltd.

AEI-Birlec Ltd have received a contract to supply continuous tray pusher furnaces, gas carburizing furnaces, and sealed quench furnaces to the Czechoslovak vehicle manufacturing industry, valued at more than £400,000.

Wellman Smith Owen Engineering Corporation have received orders worth about £2 m. for steelworks plant and equipment, including orders for rolling mill plant, for an LD-AC oxygen steelmaking unit for Stewarts and Lloyds, and for mill cranes for Shelton Iron and Steel Ltd.

Powell Duffryn-Coppee Limited have received a contract valued at over £500 000 for a battery of 25 coke-ovens and ancillary plant for the Rhodesian Iron and Steel Company, Redcliff, Southern Rhodesia.

# INDUSTRIAL PUBLICATIONS RECEIVED

Nickel in SS Canberra, available from the International Nickel Company (Mond) Ltd, describes briefly the use that has been made of nickel in the construction and fitting out of the

Factory Planning and Installation describes and illustrates plant produced and installations carried out by Thos. W. Ward Ltd. Talking about Wards outlines the whole of the same company's activities.

Ampco spark-resistant tools, a leaflet, gives brief details of various safety tools, and is available from Optoshield Ltd, 146 Clerken-

well Rd, London EC1.

Vokes Autoroll mark II is an explanatory leaflet describing an improved version of an automatic air filter.

Holmes-Elex Electrical Precipitators describes the many dust control problems in industry, and outlines the principle of electrical precipitation and its application.

Research and development department is a booklet produced by AEI-Birlec describing the activity carried out in this new department.

GKN House, a booklet published by Guest,

Keen and Nettlefolds group, is an attractively produced description of the main features of the group's new office block in London.

Crucilite describes silicon carbide elements manufactured by the Morgan Crucible Group for electric furnaces.

# CHANGES OF ADDRESS AND TITLE

The Associated Octel Company Ltd is the new name of The Associated Ethyl Co. Ltd; the company's legal position, structure, contract arrangements, and addresses remain

unchanged.

Hunslet (Holdings) Ltd, parent company of Materials Handling (Great Britain) Ltd, is allocating greater facilities to the subsidiary. Production and personnel have been transferred from Maidenhead to the works of the Hunslet Engine Co., Jack Lane, Leeds 10 (Leeds 32261). The London and Maidenhead offices have been merged and are located at the Hunslet Group London offices, Locomotive House, 30-34 Buckingham Gate, London SW1 (SUL 2875-6-7-8).

The coal preparation and mining division of Simon-Carves Ltd is being transferred to Carlisle. From 31 December 1961 its new address will be: Simon-Carves Ltd, PO Box 26,

Durranhill, Carlisle.

The Petroleum Times is now at: Temple Press Ltd, Bowling Green Lane, London ECl.

Press Ltd, Bowling Green Lane, London Edit.

Hack Saws Ltd are now at Aven Works,
Maltby, Rotherham, Yorkshire (Maltby 2391).

John Miles and Partners (London) Ltd are
now at Moor House, London Wall, London

1002 (MER 10471) EC2 (MET 0471).

Steel and Company Ltd have moved into new London headquarters at Steel House, Eastcote, Pinner, Middlesex.

Crofts (Engineers) Ltd are now at 36-42 Tanner Street, Bermondsey, London SE1 (HOP 7751/4).

The British Productivity Council has moved

to Vintry House, Queen Street Place, London EC4 (CEN 9613).

P.G. Engineering Ltd has changed its name

The Power-Gas Corporation Ltd.
The Water Research Association is now at Medmenham, Marlow, Bucks Ferry Lane,

(Hambleden 282).

Renold Chains Continental Ltd have opened an office at 1 Allee Y Verte, Brussels, Belgium.

The Middlesbrough office of Honeywell Controls Ltd is now at 59-60 Albert Road. The telephone no. 4.43.31/32 is unchanged.

# FORTHCOMING CONFERENCES

# Symposium on aspects of vacuum science and technology

The Institute of Physics and the Physical Society has announced a one-day symposium on 'Some aspects of vacuum science and technology', at Imperial College of Science and Technology, London, on 5 January 1962.

The scope of the symposium will be: (a) con-

tinuously exhausted bakeable vacuum apparatus for pressures below 10<sup>-9</sup> mm Hg and (b) the controlled deposition of evaporated film.

Further details and application forms should be available by the end of October 1961, from the Administration Assistant, The Institute of Physics and The Physical Society, 47 Belgrave Square, London SW1.

# Physics of graphite-moderated reactors

The Institute of Physics and The Physical Society is sponsoring a symposium on 'physics of graphite-moderated reactors' Bournemouth from 4 to 6 April 1962, for the British Nuclear Energy Conference. Provisional arrangements include a visit to the atomic energy establishment at Winfrith, Dorset. Further details are available from the sponsors at 47 Belgrave Square, London SW1.

# 2nd international conference on stress analysis

The Joint British Committee for Stress Analysis has announced more details of the second international conference, which will take place from 10 to 14 April 1962, at 1 Ecole Superieure de l'Aeronautique, Boulevard Victor, Paris 15e. It is intended that contributions should deal mainly with the results of experimental work, and no review papers will be invited. Registration for the conference, including summaries of papers, is expected to be about 60NF. The official languages of the conference will be English, French, and German, and it is hoped that simultaneous translation facilities will be available. Further details are available from the secretariat at 1 Birdcage Walk, London SW1, to whom offers of papers should be sent.

# DIARY

5 Oct. LEEDS METALLURGICAL SOCIETY -Lecture 'The strength of alloys', by Prof. R. W. K. Honeycombe – University Staff House, University

Road, Leeds, 6.30 pm. society for analytical chem-10 Oct. ISTRY - Joint meeting of North of England section and Physical Methods Group, with Modern Methods of Analysis Group of the Sheffield Metallurgical Association: lectures, 'Application of atomic

absorption spectrometry to metal-lurgical analysis', by W. T. Elwell, and 'Some interferences in flame photometry', by M. S. W. Webb and P. C. Wildy – Conference Room, BISRA, Hoyle Street, Sheffield 3, 7 pm.

11 Oct. MANCHESTER METALLURGICAL SO-CIETY Presidential address by W. L. Harper – Manchester Literary and Philosophical Society, ary and George Street, Manchester, 6.30 pm.

11-13 Oct. BISRA - Conference, 'Hydrogen in steel' - Harrogate.

NORTH WALES METALLURGICAL SO-CIETY – Lecture 'The blast-furnace', by J. J. Evans – Flintshire Tech-11 Oct. nical College, Connah's Quay, nr. Chester, 7 pm.

EAST MIDLANDS METALLURGICAL SOCIETY - Lecture 'Some aspects of metallurgical training', by M. I. 12 Oct. metallurgical training', by M. I. McIntyre – Derby and District College of Art, Green Lane, Derby,

7.30 pm. 12 Oct. LIVERPOOL METALLURGICAL SOCI-ETY - Presidential address, 'Metallurgy and the craftsman', by F. R. Brace - Department of Metallurgy,

University, Liverpool 3, 7 pm. WEST OF ENGLAND METALLURGICAL 13 Oct. SOCIETY - Lecture 'Creep, the potential of theory in practice', by D. McLean - Bristol College of Technology, Bristol 7.

16-20 Oct. SOCIETE FRANÇAISE DE METAL-LURGIE - Journées métallurgiques - Maison de la Chimie, 28 bis, rue Ste Dominique, Paris 7e.

16-18 Oct. INSTITUTE OF METALS - Conference 'Metallurgy of beryllium' - Royal Commonwealth Society, Craven Street, London W2.

IRON AND STEEL INSTITUTE SPECIAL 19 Oct. IRON AND STEEL INSTITUTE OF MEETING IN USA AND CANADA - Inaugural Session, New York.

WEST OF SCOTLAND IRON AND STEEL INSTITUTE - Presidential 19 Oct.

address by Dr R. Hunter. SOCIETY OF INSTRUMENT TECHNOLOGY - Lecture 'Mechanizing factory shop floor form filling', by W. H. Baker - Manson House, Portland Place, London W1, 7 pm. 25 Oct.

25 Oct. MANCHESTER METALLUTGICAL SO-CIETY - General discussion, 'Education in the metallurgical field' Literary and Philosophical Society George Street, Manchester, 6.30 pm (see p.191).

EFFLUENT AND WATER TREATMENT 31 Oct.-EXHIBITION - Seymour Hall, Lon-3 Nov.

MANCHESTER METALLURGICAL SO-1 Nov. CIETY - Lecture, 'Problems associated with the welding of heavy sections', by A. F. Gifford - Literary and Philosophical Society, George Street, Manchester, 7.15 pm.

2 Nov. LEEDS METALLURGICAL SOCIETY -Joint meeting with The Institution of Metallurgists - details to be announced.

8 Nov.

NORTH WALES METALLURGICAL SO-CIETY - Lecture 'Recent research on steelworks refractories', by Prof. J. White - Flintshire Technical College, Connah's Quay, nr. Chespm.

LIVERPOOL METALLURGICAL SOCI-9 Nov. ETY - Lecture, 'Metallurgical aspects in the development of fast fission reactors', by Prof. C. R. Tottle - Department of Metallurgy, University, Liverpool 3,

EAST MIDLANDS METALLURGICAL 9 Nov. EAST MIDIANDS METALLURGICAL SOCIETY - Lecture, 'Electron beam welding', by M. Harper - Derby and District College of Art, Green Lane, Derby, 7.30 p.m.

# BRITISH IRON AND STEEL INDUSTRY TRANSLATION SERVICE

The following translations are now available, in addition to those given on page 82 of the September 1961 issue of the Journal. When ordering, please quote the number in bold type.

Comminution in vibratory mills. (From German.) BATEL, W., Chemie-Ingenieur-Technik, 1958, 30, Sept., pp.567-572. (£4 15s.) 11594

The calculation and operational safety of steam boilers. (From Czech.) Bettzleche, P., Hutnicke Listy (Prague), 1959, 14, (12), pp.1169-1171. (£2 10s. 0d.) [1676]
The significance of the latest technical progress on reconstruction of the rolling mill of an integrated iron, and stealwarks with special

gress on reconstruction of the rolling mill of an integrated iron and steelworks with special reference to the light-section mill train. (From German.) SCHMIEDING, H., Stahl Eisen, 1960, 80, Feb. 4, pp.150–159. (£6)

Problems of cutting temperatures during machining. (From German.) LEHWALD, W., Industrie-Anzeiger, 1959, 81, Aug. 4, pp.27–30. (£4 5s. 04)

(£4 5s. 0d.)

Differential determination of oxygen in metals by bromination-reduction. (From French.) Durand, R., and Nouvrigar, F., Rev. Mét., 1960, 57, April, pp.347–353. (£3 10s. 0d.) [1796] 3 10s. 0d.) [1796]
Determination of oxide inclusions in killed

and partially killed carbon and low-alloy steels. (From German.) PIPER, E. et al., Radex Rund., 1957, Sept., pp.727-737. (£4) [2006]

The effect of the thickness and the thermal

conductivities of the refractory linings in the blast-furnace bottom on the temperature field of the bottom. I. (From Chinese.) Wan Shu-Ming, Acta Met. Sin. (Peking), 1959, 4, Sept., pp.195-205. (£15) [2015]

Some problems of the heat flow through the blast-furnace hearth with carbon lining. II. (From Chinese.) WAN SHU-MING, Acta Met. Sin. (Peking), 1959, 4, Sept., pp.206-216. (£15)

The manufacture of partly chilled rolls from spheroidal graphite cast iron. (From Polish.) RUSIEW, R. D., Prz. Odlew., 1960, 10, (4), pp.106-111. (£4 5s. 0d.) [2020

Structural examination of iron and steel with the electron microscope. (From German.) SCHRADER, A., Schweizer Archiv, 1960, April, pp.163-170. (£4 10s. 0d.) [2044]

Spectrometric ultimate analysis of crude and industrial silicate materials. (From German.) RICHTER, H., and JOHANSSON, S., Tonind.-Ztg. u. Keram. Rund., 1960, 84, Feb. 20, Ztg. u. Keram. Rund., 1960, 84, Feb. 29, pp.77-88. (£6 5s. 0d.) [2046]
Forward flow and coefficient of friction in

rolling. (From Russian.) Golubev, T. M., and

ZAIKOV, M. A., Issledovanie protsessov obrabotki metallov davleniem. Vypusk I. (Research on processes of metalworking by pressure, issue No.1). Trudy Sibirskogo metallurgicheskogo instituta im S. Ordzhonikidze; Sverdlovsk, Metallurgizdat, 1954, pp.69-121

The behaviour of the mechanical properties of ferromagnetic materials in a magnetic field. II. (From German.) Jahn, H., Die Technik, 1958, 13, (2), pp.94–99. (£5 5s. 0d.)

Plastic strain and fracture of steel specimens subjected to a cylindrical state of stress. Application to the study of the hydrogen embrittlement of steel. (With discussion.) (From French.) LIANG, K. et al., Rév. Mét. Mém. Sci., 1960, 57, March, pp.203–214. (£5 5s. 0d.)

Stabilizing annealing and its effect on the corrosion-resistance of 1 Kh18N9T steel. (From Russian.) BABAKOV, A. A., and KAREVA, E. N., Spetsial'nye Stali i Splavy, Sbornik trudov, vypusk 17 (Special steels and alloys. Coll. of papers, issue No.17.) Tsentr. Nauch. Issled. Inst. Chernoi Met. (TsNIIChermet). Inst. Kachestvennykh stalei, pp.204–227. Moscow, Metallurgizdat, 1960. (£7 5s. 0d.) [2123]

The susceptibility of chromium-nickel-molybdenum-copper steels to intergranular corrosion. (From Russian. ZOTOVA, E. V., ibid., pp. 295-310. (£4 5s. 0d.)

[2124]

pp. 295–310. (24 38. 0a.)
Pitting of chromium stainless steels. (From Russian.) BABAKOV, A. A., and TUFNANOV, D. G., 'sbid., pp. 184–203. (£5 10s. 0d.)
Screws in the high temperature range. (From German.) STANGE, E., Eleektrizitätswirtschaft.

1960, 18, Sept. 20, pp.642-646. (33) [2161]
The extrusion of steel tubes and sections. (From German.) Haffner, E. K. L., and Elkan, R. M. L., Neue Hitte, 1960, 5, May, pp.266-278. (55 15s. 0d.)

Appearatus for the isolation of residues in

Apparatus for the isolation of residues in alloyed and unalloyed steels according to P. Klinger and W. Koch. (From German.)
STRÖRLEIN and Co., Düsseldorf (pamphet.

5 pages). (£2) [2142 Calculation of the coefficient of friction in the working of metals by pressure, based on the theory of the slip band. (From Russian.) IVANOV, P. A., Kuznechno-Shtampov., 1960, 2, (10), pp. 46. (£2 15s. 0d.) [2148]
Semi-automatic device for indicating the

dimensions of large blocks during forging on hydraulic presses. (From Russian.) BYCHKOV, O. D., Kuznechno-Shtampov., 1960, 2, (10), pp.30–35. (£4 5s. 0d.) [2149]

Directional dependence of magnetic properties in electrical sheet and its measurement. (From German.) Ruess, J., Elektro-technische Zeitschrift-A, 1959, 80, Sept. 1, pp.588-593

Inhibiting the strain ageing of non-alloy, low carbon structural steels by means of phosphorus. (From German.) Erdmann-Jesnitzer, F. et al., Bergakademie, 1960, 10, Oct., pp.559-567. (£5 15s. 0d.)

The determination of nitrogen in steel, iron, and ferro-alloys. (From French.) CALMETTES, J., and Guinot, H., Rev. Mét., 1960, 57, Oct., pp. 925–933. (£3 15s. 0d.) [2166]
Analysis of hydrogen, oxygen, and nitrogen

in metals under reducing conditions in argon. (From French.) HANCART, J., and MAROT, J., Rev. Mét., 1960, 57, Oct., pp.911-917. (£4 5s.)

Metallographic investigation of cracks in High temperature steel creep specimens. (From German.) Horn, E., *DEW Techn. Ber.*, 1961, (1), pp.17–19. (£2 5s. 0d.) [2178]
The effect of copper on the corrosion behavior

viour and mechanical properties of austenitic chrome-nickel steels. (From German.) RAM-CHANDRAN, T. et al., Arch. Eisenhüt., 1961, 32, March, pp.173-185. (28 5s. 0d.)

The welding behaviour of chemically resistant Cr-Ni steels with higher Mo and Mo-Cu contents. (From German.) Schmidt, A. Schweisstechnik, 1958, 12, Dec., pp.153-156.

Electric resistance welding of tubes at higher frequencies. (From German.) BOHNEN, J. K., Blech, 1969, 7, (10), pp.650-653. (£2 10s.)

T2204 Progress in the field of electrical sheets.

(From German.) HESSELBACH, H. Technica, 1959, Nov. 20, pp.1333-1338. (£4 15s.

Basic refractory waste—a valuable raw material. (From Russian.) Kaibicheva, M. N., et al., Metallurg, 1961, Jan., pp.18-20. (£2 10s. [2223

A brief survey of the use of waterglass in the manufacture of welding electrodes. (From Czech.) VIDRMA, J., Zváranie, 1960, 9, Aug., pp.242–245. (£4 5s. 0d.) [2227]
Symbols, classification, and quality stan-

Symbols, classification, and quality standardization for submerged are welding powders. (From German.) Becker, G., Schweisstechnik, 1960, 10, (5), pp.175–178. (£3) [2258]
A new light-section rolling mill for special steel. (From German.) Bersa, G., Stahl Eisen, 1961, 81, April 27, pp.572–578. (£4 158. 0d.)

Investigation under operating conditions of A hot slab or billet shear. (From German.)
Kreulitsch, H., Bänder, Bleche, Rohre, 1961,
Jan., pp.1-5. (£3 15s. 0d.)
Isothermal transformation diagrams for

Martensitic stainless steels adopted as Swedish standard. (From Swedish.) MOLINDER, G., Jernkont. Tekn. Rad. Medd., 1961, 20, (261), pp. 723-732. (£2) [2270]

Operating experience with flame spectrometers in the determination of calcium and magnesium in steelworks laboratories. (From German.) ABRESCH, K., and DOBNER, W., Arch. Eisenhütt., 1958, 29, Jan., pp.25–34. (£9 15s. 0d.) [2271

The importance of edging passes in the rolling of blooms. (From Polish.) Leskiewicz, W., Hutnik (Poland), 1958, 25, (10), pp.386–390. (£4 10s. 0d.) [2272]

390. (£4 10s. 0d.)

Methods of removing surface defects from raw materials before rolling. (From Polish.)

TYLUSINSKI, M., Hutnik (Poland), 1960, 27, (5), pp.182-188. (£4 15s. 0d.)

Measurements of the flow of coal dusts in pipelines. (From German.) HÜBEL, E., VGB

Mitt., 1960, Aug., pp.230-242. (£5 5s. 0d.)

[2277]

New knowledge of pickling with phosphoric

New knowledge of pickling with phosphoric acid and the treatment of waste water. (From German.) MORAN, R., Metall-Rein. Vorbeh., 1960, 9, May, pp.69-71. (£2 10s. 0d.) [2280]

Automatic submerged arc welding of thin-walled pipes of small diameter. (From Czech.) SVERCL, J., and VYSOUZIL, S., Zváranie (Bratislava), 1960, June, pp.177–178. (£2 5s.)

Modernization of equipment and speeding up the processes of manufacturing phthalic anhydride. (From Russian.) LITVINENKO, M. I., Zhur. Vsesoyuz. Khim. Obshchestva, 1961, 6, (1), pp.81–87. (£5 10s. 0d.) [2303]

The effect of manganese content on ingot mould life. (From German.) Kiesel, K.-L., Van Hills, 1061, 6 May 1924, 16315s.)

Neue Hütte, 1961, 6, May, pp.284-291. (£3 158

Properties of rustless austenitic chromiumrepetries of rustless austentic chromium-nickel steels containing boron for nuclear reactor construction. (From German.) Bun-GARDT, K., and OPPENHEIM, R., Arch. Eisenhüt., 1961, 32, Feb., pp.95–101. (‡3 15s.) 2305

Specifications for standard dimensions of three-phase motors for intermittent service in iron and steelworks. (From German.) Schönig, H., Stahl Eisen, 1956, 76, Oct. 4, pp.1290–1292.

Increasing the erosion strength of steel for steam-turbine blades by spark-hardening. (From Russian.) TIMERBULATOV, M. G., and SAVUKOV, V. P., Energomash., 1961, 7, April, pp. 32–34, 40. £3 10s. 0d.) [2316]

pp. 32-34, 40. (£3 10s. 0d.)

The two-colour pyrometer. (From French.)

Rodice, P., and Maillot, G., Rev. Mét., 1955.

52, June, pp. 477-484. (£5 5s. 0d.)

Jalousie-type dust catchers for gas cleaning.

(From Russian.) KANFER, V. D., and SHKLYAR,

M. S., Metallurg, 1961, 6, March. (£1 10s. 0d.)

Magnetic roasting of iron ores [In countries who are members of the S.E.V. (the East European Council for Mutual Economic Aid)].

(From Russian.) Gubin, G. V., Metallurg, 1961, 6, March. (£2 15s. 0d.) [2338]
Mathematical investigation of the drawing process. (From German.) Siebel, E., Stahl Eisen, 1952, 72, April 10, pp.425–426. (15s. 0d.)

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# ABSTRACTS OF CURRENT LITERATURE Iron and Steel Manufacture and Related Subjects AND BOOK NOTICES

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# **ABSTRACTS**

These abstracts are also available on index cards in advance of publication in the *Journal*, each abstract being classified under the Universal Decimal system (UDC). Details and subscription notes can be obtained from the Secretary, The Iron and Steel Institute.

# MINERAL RESOURCES

Europe's major source of high grade iron ore  $(Min.\ J.,\ 1961,\ 256,\ {\rm May}\ 1,\ 502-503,\ 505)\ {\rm A}$  review of Swedish orebodies.

Deposits of iron and manganese V. V. Askasinskii (Poleznye iskopaemye chitinskoi oblasti, chernye metally i nemetallicheskie poleznye iskopaemye, Academy of Sciences, 1959, 8025) This description of the iron-ore deposits of the Chita region indicates that there are industrially valuable deposits of easily beneficiated iron ores of high quality and suitable for exploitation. The discovery of Ti and potentially valuable Mn deposits is also considered to be very likely.—A.I.P.

Liberian iron-ore deposits (Iron Coal Trades Rev., 1961, 182, April 14, 802) The deposits in the Nimba range are being developed; more than 200 000 000 t are available with an average content of 65% Fe and operations are scheduled to commence early in 1963 at a rate of 5 to 6 m. t/yr., this being later increased to 10 m t. The project includes a 165 mile rail link to the port of Buchanan owned by Lamco and the Bethlehem Steel Corporation; the financial structure is indicated; the plant is to be constructed by the Grangesberg Company who will undertake the mining and the transport. Bethlehem will take a quarter of the output and most of the remainder has been placed on long-term contracts with German steelworks.

Africa's iron ore resources today P. Holz (Can. Min. J., 1960, 81, July, 68-71) A review, describing the increased activity in the iron ore mining industry in Africa, provides figures for the vast untapped resources spread throughout the continent. The South African Republic (the former Union of South Africa), the Central African Federation, Angola, Sierra Leone, the United Arab Republic, and the Sudan, French West Africa, Tunisia, Algeria and Morocco, and finally Liberia, are described seriation, with brief but pertinent data.

The Savage River iron deposits in Western Tasmania W. H. Spooner (Min. Chem. Eng. Rev., 1960, 53, Dec. 15, 55) Previously these ore bodies were known as the Rio Tinto; it was estimated that they contain  $20 \times 10^8$  t of high-grade magnetic ore but a later survey (1936)

suggested that both quantity and quality were exaggerated, the latter specially on account of the S-content. An aerial magnetic survey in 1957 followed by drilling in 1959 showed several hundred feet of medium grade Fe ore and upon the basis of this work  $50 \times 10^6$  t was reasonably proved and  $130 \times 10^6$  t inferred. Magnetic separation tests show that the ore can be beneficiated with a recovery of  $97\frac{1}{2}\%$  Fe to a grade of 65-67% Fe, a substantial amount of S and P being removed;  $\frac{1}{4}-\frac{1}{4}\frac{3}{4}\%$  TiO 2 present in the concentrate was imperfectly removed. The question of location and transportation is raised and electric smelting is suggested to combat the Ti problem.—c. v.

Plans announced for major projects to develop iron ore and bauxite deposits (Min. Chem. Eng. Rev., 1960, 53, Dec. 15, 63–64) The Western Australian government and the Broken Hill Proprietary Co. Ltd, have agreed to establish an integrated iron and steel industry at Kwinana, south of Perth. This will involve £80 m. and a lease has been granted to BHP of the Koolanobbing-Dowds-Bungalbin iron ore deposits NE of Southern Cross which have been proved to contain at least 10<sup>8</sup> t of high-grade ore. Coking coal will have to be transported from N.S.W. to W.A. and other essential materials will have to be brought in from other states. The Kwinana programme includes a blast-furnace with a capacity of not less than 450000 t/year using 800000 t ore and a steelmaking plant with a minimum capacity of 330000 t/year. Kaiser Aluminium and Chemical Corp. Ltd, USA, and Consolidated Zinc Corp. Ltd are investing £140 m. to develop an integrated Al-industry in Australia and NZ which is to be operating by 1966; this includes bauxite mining and 360000 t/year alumina plant at Weipa, North Queensland and Al-smelter at Invercargill. There is to be an expansion Bell Bay to a capacity of at least 28000 t or more so as to double the NZ output of 240000 t.—C.V.

Nickel. The Canadian Mineral Industry—in retrospect C. C. Allen (Can. Min. J., 1959, Annual Review, 1960, 81, Feb., Part 3, Mineral Reviews, 137-138) The industry is described with special references to International Nickel at Sudbury, the Falconbridge

and Sherritt Gordon mines, and a brief reference to the penetration of Japanese interests with a three-year contract for the production of Giant Nickel Mines Ltd in British Columbia. Ore reserves generally are presented as being the highest in history.

Iron Ore. The Canadian Mineral Industry—in retrospect R. B. Elver (Can. Min. J. 1959, Annual Review, 1960, 81, Feb., Part 3, Mineral Reviews, 143–147) A review of Canadian iron ore developments in 1959 is presented with tabulated data of production by provinces, including Newfoundland (Labrador) and a list of companies under development with announced plans for production. Prices and tariffs are discussed with the indication that neither Canada nor US maintain tariffs on iron ore.

Molybdenum. The Canadian Mineral Industry—in retrospect V. B. Schneider (Can, Min. J., 1959, Annual Review, 1960, 81, Feb., Part 3, Mineral Reviews, 151–152) The output of the sole Canadian producer, Molybdenite Corp. of Canada Ltd for 1959 is described and discussed, with data on exploration by other concerns. A list of the more important Canadian consumers of molybdenum primary products is given with an indication that the price is set by American Metal Climax Inc, A table summarizing annual production, exports, and consumption for 1955–1959 is appended.

Cobat. The Canadian Mineral Industry—in retrospect V. B. Schneider (Can. Min. J., 1959, Annual Review, 1960, 81, Feb., Part 3, Mineral Reviews, 154) No cobalt ores were mined in Canada during 1959. Production 1600 t approx. valued at nearly \$16 m., was obtained as a by-product from the silver ores of the Cobalt-Gowganda area of Ontario, and from the smelting and refining of the nickel-copper ores of Sudbury, Ontario, and Lynn Lake, Manitoba, areas.—s.H.-S.

Metalliferous deposits in the Nelson area. Molybdenum deposits H. W. Little (Can. Mines Geol. Survey, Memoir 308, Cat. no.M46-308, pp.205, 193) Although many properties in the Nelson area contain molybdenite in their ores, only from the Molly, which is south of Lost Creek, has any production been recorded.

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Metalliferous deposits in the Nelson area. Iron-oxide deposits H. W. Little (Can. Mines Geol. Survey, Memoir 308, Cat. no.M46-308, pp.205, 193-194) Only one property in Nelson map-area (west half) has produced iron oxides

<sup>\*</sup> Abstracts, the reference to which is marked with an asterisk, are or are to be made available as translations.

The Duncan range iron deposits near Fort George, Quebec W. N. Ingham (Can. Min. J., 1960, 81, April, 110-111) These deposits consist of alternate quartz-rich and magnetite-rich layers; six main ore areas are distributed along 15 miles and two exist parallel but further to the south. The details are given but the average feasible depth of open pit mining, 600 ft, shows that about two billion tons could be extracted; the average grade of all the iron ore is 32% but 15 metallurgical tests from 12 outcrops show that with a min. grind of 200 mesh a magnetic concentrate of 66.06% Fe can be produced; there is a 6.6% Si conen. and a negligible amount of Ti, S, and P. Transportation of the concentrate to a steelmaking centre a problem to be solved as it would appear that 600 miles is involved.—c.v.

Vanadium-uranium deposits of the Rifle

Vanadium-uranium deposits of the Rifle Creek area, Garfield County, Colorado R. P. Fischer (US Atomic Energy Comm. Geol. Survey Bull., (1101), 1960, pp.52) The deposits of the area are described, with a section on mineralogy by T. Botinelly. The area has yielded about 750000 t of V-U ore, mostly from the deposit in the Navajo and Eutrada sandstones. The ore contains  $1-3\,\%V_2O_5$  and several hundredths  $\%U_3O_6$ ; ore from the Morrison formation has about the same V content but a little more U.—S.H.-S.

On the depth of bodies producing local magnetic anomalies R. A. Smith (Q. J. Mech. Appl. Math., 1959, 12, Aug., 354-364) Some inequalities relating to magnetism are proved, their relevance to the interpretation of local anomalies in the earth's magnetic field is discussed. From observations of the resolved part in any one direction, of the earth's magnetic field, these inequalities could be used to calculate (subject to certain hypotheses) a maximum possible value for the depth below the earth's surface of the top surface of the magnetized body producing the anomaly.

# ORES-MINING AND TREATMENT

The 4000 tons per mining machine at Kiruna in Sweden Luossavaara-Kiirunavaara Co. (Mines et Met., 1961, May, 277–279) [In French] A description of modern mining equipment installed in 1958 by the Luossavaara-Kiirunavaara Company capable of extracting a total of 4000 t/h in skips. Illustrations and layout diagrams are provided.

The changing iron ore industry H. S. Harrison (Eng. Min. J., 1960, 161, July, 72-73) The effects on the American ore producing industry of foreign competition, the changing character of the iron ore industry and the present oversupply of iron ore are discussed.

Total utilization of iron ores I. S. Shapiro (Metallurg, 1960, (6), 14-16) [In Russian] Complete utilization of ores means the use of all constituents including residues from beneficiation. This is generally practised today in the petroleum and wood industries, non-ferrous ore treatment, and in a range of food products. Ferrous metallurgy uses ores containing between 25 and 65% of iron and also a large number of metallic and other substances. At present only Ti ores are utilized in full and a large beneficiating plant is under construction

for the Katchkanar ores.

Durgapur—A Technical Survey, technical

Durgapur—Burgiasl considerations T. P. Coland metallurgical considerations T. P. Col-clough (Iron Coal Trades Rev., 1960, pp.218, 14-15) Available coal and iron ore supplies are discussed together with the preparation of the ore. The first steelmaking operations at Durgapur will be the OH process; as no bought scrap is available, the furnaces will operate almost entirely on hot metal and scrap arising within the works. Provision for desulphurizing is made but the necessity for this step is considered unlikely; Si will be removed by blowing the hot metal in deep ladles by surface blowing with O<sub>2</sub>; some of the C may also thus be

removed. An  ${\rm O_2}$  plant has been installed to generate 100 t/day but an increased in this figure is envisaged in due course.—c.v.

Beneficiation of red iron ore fines from Pine Mine, Bessemer, Alabama W. E. Lamont, I. L. Feld, and B. H. Clemmons (US Bur. Mines Rep. Invest. 5779, 1961, pp.16) A detailed tabulated report is presented on work carried out in cooperation between the Federal Bureau of Mines and Woodward Iron Co. to investigate methods for beneficiating the minus in fraction of mine run ore from the company's Pyne mine, approximately 5 miles SE of Bessemer, Ala. The results are reported and discussed.

Extraction of alumina, iron and sodium oxide from red mud L. P. Ni (Izvest. Akad. Nauk, Kazakhskoi SSR, Seriya metallurgii. obogashcheniya i ogneuporov, Issue 1 (7), Alma-Ata, 1960, 21–26) A method is recommended for the complex utilization of the basic components of mud obtained as a result of the reworking of high-silicon and high-iron content bauxites using the Bayer process (6 refs).—A.I.P.

The principles of fluidized solids roasting F

Schytil (Metall Gesellschaft, 1959, (1), 13-29) The development of fluidized solids roasting is discussed from the theory and practice and the machinery described. The roasting of sulphides

machinery described. The roasting of suprimes is dealt with as an example (11 refs).—R.P.

The 'Haematite meeting' of the Swedish Mining Association and Jernkontoret O. Ödman, P. G. Kihlstedt, S. Eketorp, B. Kalling, S. Sjöberg, A. Brolin, S. Anestad, and O. Nyquist (Jernkont. Tek. Rad., 1959, 20, (257), 475-579) In 1959 a special meeting was held at which a number of speakers reported the latest developments in the field of hematite iron ores with subsequent discussions. These are reproduced here and deal with these iron ores, their concentration, magnetizing reduction, concentration aided by Humphreys spirals, concentration-flotation, sintering of hematite fines and utilization of the highly concentrated fines

Milling plants in Canada: metallic ores (Can. Mines Tech. Surv., 1960, M36-60/3-1, pp.43) A list of mills treating metallic ores in Canada, with the principal mining companies tabulated and brief notes giving current status of each mill. Trends in mineral dressing are indicated Mineral Processing Division of the

Mines Branch.—s. H.-s

Beneficiating manganese oxide ores from the Butte-Philipsburg federal stockpile G. V. Sullivan, W. A. Stickney, and R. C. Bush (US Bur. Mines, Rep. Invest., 5728, 1961, pp.19).
On the enrichment of Lorraine siliceous minerals by chemical treatment E. Herzog and

L. Bäcker (Compt. Rend., 1961, 252, May 3, 2716-2717) The treatment is discussed.

New vibrating screen improves iron ore processing B. Fagerberg (Eng. Min. J., 1960, 161, July, 88-91) The use of L-screens at the Malmberget plant of Luossavaara-Kiirunavaara Co., Sweden is described.

Counterflow sizer benefits spirals J. Thompson (Eng. Min. J., 1960, 161, July, 84–85) Using the device described, plants using Humphreys Spiral Concentrator circuits can obtain higher recovery from coarse feeds, without the need for a jig or heavy media section; and cleaner circuits can be reduced in

Briquetting iron ores B. M. Ravich (Metallurg, 1960, (6), 9-11) [In Russian] The brown Laubakh ores containing about 40% of soft weathered ores with a large percentage of moisture have the following composition:
35-39%Fe; 12-15%SiO<sub>2</sub>; 7-8%Al<sub>2</sub>O<sub>3</sub>; and 4-6%Mn; and 1-3%CaO. Owing to their mechanical properties and high content of fines these ores are unsuitable for use in metallurgical plants without briquetting. This operation consists of mixing the ore concentrates with reducing agents, fluxes, and binders, compacting and hardening the briquettes. Suitable presses are described.

Progress in steelmaking—greater use expected for sintered, pelletized ores M. J. Greaves and A. English (Steel, 1961, 148, May 8, 132, 136) Various studies on the growing use of sintered and pelletized ores in UK, Japanese, Swedish, and Australian plants

and/or laboratories are reported,—s.H.-s.

The sintering of fines by the shaft sintering process W. Wenzel and H. Schenck (Stahl

Eisen, 1961, 81, March 30, 404-407) A pilot plant for shaft sintering of fines is described and illustrated. The shaft sintering process is a continuous process without any conveyor belt and the like. Another advantage is the use of compressed air instead of custion constitution. compressed air instead of suction operation. The floor space of the vertical-shaft is much smaller than that of any of the conventional conveyor-type plants. Shaft sinter shows a somewhat higher strength than ladle sinter, its reducibility and degree of oxidation are therefore slightly inferior to conventional sinter, but these differences are not material and are

but these differences are not material and are fully compensated by the advantages gained.

Production and smelting of high limestone bearing sinter with special reference to desulphurization of sinter and pig iron B. Weilandt and F. Kruse (Stahl Eisen, 1961, 81, March 2, 295-302) It is advantageous to add the limestone to sinter instead of to the burthe limestone to a sinter instead of to the burden if the burden requires a high limestone addition for smelting in the blast-furnace. Throughput is increased and coke consumption of the blast-furnace is reduced by this process. The desulphurization mechanism is discussed in detail and it is pointed out that the coke consumption should be kept low in order to prevent an increase in sulphur take up from the coke when the slag is saturated with

sulphur.-T.G The use of long-flame coal and hot blast on sintering strands for sintering minette ores K. Heyden (Stahl Eisen, 1961, 81, April 13, 498– 501) The sinter plant of Röchling Werke which is more than 30 years old is described, together with modifications introduced during that time with respect to the use of long-flame coal instead of the conventional coke dust, which is in short supply there so that the fuel is up to 80% coal. The costs have been reduced by the use of coal and the milder fire is of advantage to the sintering process, but the rather high proportion of volatile constituents in the flue gas has to be put up with. Further savings were achieved by the use of hot blast, these are so substantial that they paid for the installation of the plant in a very short time.

Control of sinter plant operation B. Weilandt and N. Petrusch (Stahl Eisen, 1961, 81, Feb. 16, 235–239) The efficiency of sinter plants lies below that obtained in ladles owing to lack of control of the optimum values for carbon and humidity. This deficiency can be measured by waste gas analysis. An apparatus is also described for determination of the humidity content of the sinter mixture. The readings are continuous and are recorded.-T.G.

Testing of the strength of sinters A. Send and B. Weilandt (Stahl Eisen, 1961, 81, March 2, 303-310) The authors review the methods quoted in the literature for testing the strength of sinter. They found that the drum test under specified conditions gives results that are in good agreement with the behaviour of the sinter under actual working conditions. To support this view the authors conducted a number of tests the results of which are reported in tables and graphs (17 refs).—T.G. Magnetic roasting for Mesabi semi-taconites

M. A. Hanna Co. and Dravo Corp. (Eng. Min. J., 1960, 161, July, 73) A note on plans to build pilot plants to develop an economic process for treating these low-grade, non-magnetic ores.

Burning limestone in vertical furnaces A. G. Romanenko (Metallurg, 1960, (5), 38–39) [In Russian] The OH furnaces at 'Azovstal' smelt a high phosphorus pig iron and require large quantities of lime for dephosphorization to be added during the charging period. There was therefore constructed in 1957 a plant with a capacity of 190000 t yearly. It consists of four vertical kilns of 325 m<sup>3</sup> each and operates on Elenovsk limestone chiefly of 25-80 mm particle size. Composition 52-54 %CaO; 0.5-1.2 %MgO; 0.6-2.5 %SiO<sub>2</sub>. Losses on burning about 43 % fired with coke. A description of the kilns and installation is given.

# FUELS-PREPARATION, PROPERTIES AND USES

Experience in the carbonization of brown coal briquettes at Morwell R. S. Higgins and G. L. Kennedy (*Proc. Austral. IMM*, 1960, no.195, Sept., 65–102) A pilot Lurgi carbonization plant was used. Under conventional operating conditions the thermal efficiency was very high but the physical quality of the char was extremely poor. Using a slow drying rate, an improvement in the size of the char was obtained but a similar approach in the carbonization state was not possible due to inadequate control over the heating. Examination of the heat exchange process showed that the severe heating of the briquettes entering the carbonizer is a characteristic of this process and cannot be controlled by modification. The plant has been closed down to allow a reconstruction of the heating system so as to obtain hard char.—C.V.

Development of brown coal char as a new metallurgical fuel R. S. Higgins, G. L. Kennedy, and D. G. Evans (Proc. Austral. IMM, 1960, (195), Sept., 103-116) Although hard char satisfies the requirements of a metallurgical fuel (high C-content and strong coarse lumps) the physical state of the C differs and it reacts more readily with oxidizing gases than conventional coke does. This hard char is almost unique and the problem is not to reduce the activity but to increase the lump size; it has a low ash content. A 3in size is suggested for foundry cupolas, lin for domestic enclosed stoves, and ½in is considered for steam locomotives, carburized steel in electric furnaces etc. The future of this hard char to blastfurnace smelting of metal ores and in the smelting of non-ferrous metals is discussed.

Durgapur—A technical survey, coke ovens and by-product plant (Iron Coal Trades Rev., 1960, pp.218, 54-65) The washing plant is designed to deal with 306 t/h of 3in to zero raw coal. Washed Jharia coal is mixed with other coals to give a blend with 16-5% ash; it carbonizes to give an acceptable blast-furnace coke. The washing process is sufficiently flexible to deal with other types of coal. The various stages of the process are dealt with. The Robins Messiter system of coal stocking, blending, and reclaiming is used. There is a total of 234 coke ovens in three batteries of 78 ovens each, the whole having a throughput of 5200 t dry coal per day; the oven dimensions, heating, etc., are briefly described. The by-products and their treatment are dealt with.

Coking properties of Scottish coals V. Giedroyc (Gas World, 1961, 153, April 1, 35-40) Abstract of a paper presented to the Midland Section of the Coke Oven Managers' Association entitled 'The influence of coal properties on the physical characteristics of coke and the effect of the latter on blast-furnace performance'. The effect of a research programme conducted at Colville's coke-oven plants between March 1954 and Feb. 1960 is reported.—s. H.-S.

Coking and other properties of low rank coal after mild treatment with hydrogen G. I. T. McConnell and F. J. Pinchin (Fuel, 1961, 40, March, 81–87) Low rank coals were treated with  $\rm H_2$  by heating to 400°C at 200–240 atm in the presence of  $\rm Fe_2O_3$  as catalyst and gave markedly improved products compared with similar tests without the catalyst. Results are tabulated and are followed by a discussion.

The development of coke-oven machines E. Simmons and J. A. Dunning (J. Inst. Fuel, 1961, 34, March, 107-113) The history of cokemaking is traced from the time of Abraham Darby (1704) to the modern integrated steelworks. The sequence of machine operations in relation to the usual oven machines is considered and the development of the charging larry and the constructional features of a modern unit, employing electro-hydraulic controls and safeguards against smoke emission, are described. The functions of the ram machine, the construction of the coke guide and the need for adequate door cleaning facilities are discussed. A modern coke car of tubular construction is described and various systems used for obtaining alignments are considered, together with the possible future extension of automation in the coking industry.—S. H.-S.

Furnace coke production: Readjustments and developments in the USA J. B. Shallenberger (Iron Coal Trades Rev., 1961, 182, April 28, 911-912) During the last 40 years there has been a drastic change in furnace coke production and distribution in the USA, UK, and elsewhere, this being mostly due to the expansion of natural oil supplies and the

subsequent development of techniques for extracting almost the whole range of byproducts which previously had been obtained by coal carbonization. These views are discussed from the American viewpoint.—C. v.

The combustion and gasification of coke (A contribution to the classification of the processes within the cupola furnace) W. Koppe (Giesserei Techn. Wiss. Beihefts, 1961, April, 101-107) The three regions of coke combustion which differ in the effect of chemical and physical processes—kinetic at low temp., pore-diffusion at medium temp., and diffusion at high temp. are considered. In case of this the processes occurring in the cupola furnace are studied and the possibilities of changing the conditions in the various zones are discussed, (17 refs).—M.L.

Experiments on the biological treatment of phenolic effluent J. Jeffery (Gas World, 1961 153, March 4, 23-25) Experiments carried out on a large-scale plant, based on laboratory work preceding the design of the plant, are described with some data on the background.

Liquid fuel in the metal industry. A ten-year review E. B. Davies and A. B. Pritchard ('Major Developments in Liquid Fuel Firing, 1948-1959', Inst. Fuel, 1959, B-37-52) A general review in which it is stressed that the whole problem must be most carefully studied before deciding upon a new installation and secondly that furnaces and oil-firing equipment must only be purchased from reputable manufacturers since excellent furnace design has often been spoiled by inadequacy of the oil-firing equipment.—c.v.

Durgapur—A technical survey. Energy balance (Iron Coal Trades Rev., 1960, pp.218, 32–34) The coke-oven and blast-furnace gases in therms/h for Durgapur (actual and without pig production) and for a typical UK works is given and compared and steam requirements are discussed. Electrical power is estimated at 30–40 megawatts and the problem of generation v. purchase is solved by the proximity of a 132-kV transmission line of the Damodar Valley Corporation; this is designed for pulverized coal and can consume surplus discard coal and coke oven gas when available.—C. v.

Gas and energy balance of an iron and steel works J. Szczeniowski (Blast Furnace Gas, IRSID, Les Cahiers du Cessid, 1959, (4), pp.61) The energy balance in various plants in iron and steelworks is considered including modern oxygen steelmaking processes (13 refs).

Contribution to the study of the elimination of hydrogen sulphide contained in industrial gases H. Guinot, P. Le Henaff, and X. Tinchant (Chim. et Ind., 1961, 85, April, 561–575) [In French] First the main processes used at present by industry to remove H<sub>2</sub>S are reviewed, emphasizing on their advantages and disadvantages. A new experimental method is described based on the use of aqueous solutions of ferric propionate. Indefinite regeneration is possible with this. The process will be very valuable particularly when it is not really necessary to remove simultaneously the CO<sub>2</sub> which often exists as an impurity in the gases to be treated.

# AIR POLLUTION AND SMOKE

Air pollution (Steel, 1961, 148, April 3, 37-40) A brief survey of opinions of the Air Pollution Control Association of Pittsburgh and some leaders of American heavy industry on the problem, and the size of the market for such devices as electrostatic precipitators, and the possibility of federal control through Congressional action.—S. H.-S.

Sources of air pollution and contaminated atmosphere A. Laamanen (Tek. Kemian, 1961, 18, June, 205-207) Air contaminants are of two kinds: natural and those caused by civilization. Among the first group are the following: atmospheric dust, nitrogen oxide from electric discharges in nature, sodium chloride from evaporation of sea water, sulphur compounds from decomposing matter, soil and pollen dust and microbes. Among the second group, pollution is caused by settlement, industry, and traffic. Individual groups are discussed explaining the main types of damage they

New electric melting furnaces at Midvale-Heppenstall equipped for air pollution control (Indust. Heat., 1960, 27, Sept., 1810–1812) Details are given of the eight-compartment Wheelabrator Dustube collector. It deals at>99% efficiency with 85000 ft³/min of air laden with dust and fume down to  $0.5~\mu$  or less.

Electric cleaning P. Mellet (Blast Furnace Gas, IRSID, Les Cahiers du Cessid, 1959, (4), pp.32) The principles of electrical cleaning are outlined, various types of equipment are described, and a section is devoted to the electrofilter (29 refs).

Dry cleaning J. Szczeniowski (Blast Furnace Gas, IRSID, Les Cahiers du Cessid, 1959, (4), pp.24) Equipment, control, manning, testing, and economics are reviewed.

wet cleaning P. Mellett (Blast Furnace Gas, IRSID, Les Cahiers du Cessid, 1959, (4), pp.37) Characteristics of wet cleaning processes are outlined, and a detailed account of systems and equipment used is given (11 refs).

Comparison of the various cleaning systems A. Boitel (Blast Furnace Gas, IRSID, Les Cahiers du Cessid, 1959, (4), pp.23) The various gas-cleaning systems, their principles, efficiency, and economics are compared.

Crude and clean gas systems. Distribution of the gas J. Szczeniowski (Blast Furnace Gas, IRSID, Les Cahiers du Cessid, 1959, (4), pp.32) Underlying principles and methods used in gas cleaning are discussed, and problems are considered.

Electronic systems purify air for metalworking plants E. R. Koenig (Steel, 1961, 148, April 24, 152-153) Claims for the efficiency of electronic filtration of air are presented.

The electric resistance of dust in the electrical filter H.-G. Eishold (Arch. Eisenh., 1961, 32, April, 221-224) An instrument has been developed for the determination of the specific electric resistance of dust under operational conditions. It is characterized by enabling electrical precipitation of the dust sample, making possible the controlled variation of the packing density of the dust layer.—M.L.

# TEMPERATURE MEASUREMENT AND CONTROL

Temperature measurement in the steelworks G. Husson (Converter Steels, IRSID, Les Cahiers du Cessid, 1959, (41), pp. 58) The principles and operation of various methods of intermittent and continuous temperature measurement are described with examples (20 refs).

ment are described with examples (20 refs).

Absorbing filters and high-temperature optical pyrometry D. R. Lovejoy (J. Opt. Soc. Amer., 1960, 50, July, 698-706) By calculations based on spectral transmission data, it is shown that Chance ON30 neutral and Corning Pyrometer Brown glasses may be used as constant-absorption absorbing filters in optical pyrometry to measure indefinitely high-luminance temperatures with calculable accuracy. In the case of Chance ON30 glass below 2500°K, the constant absorption was confirmed by direct calibration, using a rotating sectored disc. Corrections have been calculated to 8000°K, to change from temp. based on Wien's law to temp. based on Planck's law. A number of minor precautions necessary to achieve the highest possible accuracy has been noted, and standard-deviation accuracies have been calculation for high temp. The theory of optical pyrometry has been developed, in an appendix, in a form suitable for discussion of high-temp. measurements .- s. H.-s.

# REFRACTORY MATERIALS

Refractory materials: Survey of the literature published during 1958 K. Konopicky and G. Routschka (Stahl Eisen, 1961, 81, April 13, 504-508) This instalment of the series deals with the application of refractories in the metallurgical industry, in particular in blastfurnaces and all types of steelmaking furnaces (93 refs).—T.G.

The Chinese use of refractories R. Groves (Refract. J., 1960, 36, Sept., 269-270) The present-day period is considered; the material discussed is entirely Chinese. A process of steam treatment of high Ca-Mg ores is discussed; steam is passed at 52 m³/h into a 12-t capacity cylindrical tank, temp. 480-520° and

pressure 95-100 psi for 4 h. The melt is left standing 30 min and discharged and the material contains 4–7, up to 13%CaO; yield is 2·8 t/h. It is used for bricks. The production of steel direct from ore, MgAl bricks, CrMg, and unfired Cr bricks for use in linings is dis-cussed and times and furnace temp. are indicated. The use of refractory concrete in small blast-furnaces as a substitute for fireclay brick is discussed and their use of rammed carbon linings in small furnaces is reviewed. In order to improve the performance of these linings, it is stressed that the coke must be dewatered and <1 mm in size with low ash content; likewise the coal tar and pitch must be dewatered and the mixture with a ratio coke:tar:pitch, 84:4·8:112, is previously heated, ramming taking place at 130°. The details of ramming are given. The problems with side-blown converters are reviewed since the tuyere brick lining at the top and sides of the tuyeres suffered damage. This led to the construction suffered damage. This led to the construction in a horseshoe shape with an enlarged converter mouth; this may lead to a more uniform erosion without appreciable changes in the tapping temp.-c.v

Refractory suspended construction W. S. Sinclair (Glass Techn., 1961, 2, April, 47-52) The constructions discussed are the refractory tile suspended roof which is applicable to most designs of large furnace equipment and a metal type of suspension used in conjunction with basic materials in OH slag pockets and up-Ten main considerations are listed relating to design, and the problems of erection

are discussed .- c. v

The work carried out by the research institute of the Magnesite Co. at Veitsch F. Hönig (Berg. Hütten. Monatsh., 1960, 105, Nov., 313-323) The layout, installations, and work dealt with by the institute are described. Development of a composite magnesite plus chrome magnesite refractory is discussed by way of an example of research undertaken. - R. P.

Refractory and insulating materials-nature, manufacture and applications Y. Letort (Refractory and Insulating Materials, IRSID, Les Cahiers du Cessid, 1959, (40), pp.115) The characteristics of refractories of several types are described, and their applications to the various stages of iron and steel manufacture and treatment are reviewed (152 refs).

Testing of refractories and insulating materials L. Halm (Refractory and Insulating Materials, IRSID, Les Cahiers du Cessid, 1959, (40), pp.44) Testing of the physical and chemproperties of these products is reviewed (63 refs)

An industrial test of dense magnesite brick in the lining of electroferro-alloy furnaces P. N. Babin, T. V. Demikhova, V. V. Borovichenko, B. G. Lobzhenidze, Kh. K. Kadarmetov, and P. N. Vyatchinov (Izvest. Akad. Nauk Kazakhskoi SSR, Seriya metallurgii, obogashcheniya, i ogneuporov, Issue 2 (8), Alma-Ata, 1960, 81-92) Industrial testing of a dense magnesite refrac tory in ferroalloy furnaces of the Aktyubinsk works has confirmed that refractory quality can be improved by increasing its density.

The dolomite shop A. Richard (The Thomas Steelworks, IRSID, Les Cahiers du Cessid, 1959, (5), pp.35) The equipment, operation manning, materials used, and development tendencies of the dolomite plant are discussed. Reference is made in an appendix to converter

bottoms containing metal tubes.

Loading cars in C.R.L.'s long drive  $\mathrm{C.\ J.\ W}$ Piprell and D. F. Hart (Can. Min. J., 1960, 81, May, 63–65) Canadian Refractories Ltd mines 600 t dolomitic magnesite a day. A layout of the conveyor loader is given; this operates in conjunction with an Eimco-21 mucking machine and consists of a 36in conveyor belt 86 ft long, suspended from a monorail with a clearance below for nine 3-ton cars. Negligible impact damage to the belt arises from the use of a discarded pneumatic skip wheel for loading point idlers. Initially, tubular non-toughing idlers were used but excessive belt damage would have resulted. The monorail and suspen sion were protected from impact and the mobility was retained by the use of a supporting truck at the loading end during the mucking cycle. The conveyor is made of five sections joined by flat male and female connexions.

The operation cycle is described and the

method of ventilation is indicated.—c.v.

A new experimental furnace for studying the behaviour of refractories under load at constant temperature E. Plumat and M. Jaupain (Silicates Ind., 1961, 26, March, 119-129) [In (Stiteates Ind., 1901, 20, March, 119-129) [Infrench] A new type of furnace for testing refractories under load at constant temp. is described. Five normal bricks were tested simultaneously for a given period. Test temp. of ~1500°C but at a maximum of 1700°C were used. According to the results creep resulted not only from relative changes in the con-stituent crystals but also from crystallo-graphic changes and changes in physical state. Contribution to the study of the reaction in

the solid state between lime and alumina B. Audouze (Silicates Ind., 1961, 26, April, 179-190) [In French] This article gives an analytical study, a chemical study of the reaction, an X-ray diffraction study, and an interpretation of the experimental results obtained from the

chemical and radiographic studies.

# IRON AND STEEL-GENERAL

Empiricism and science in ferrous metallurgy H. Schenck (Berg. Hütten. Monatsh, 1960, 105, Nov., 242–250) Empirical and practical aspects of iron and steelmaking are discussed. Special reference is made to Tunner's work.

Lecture notes on iron and steel: Raw materials (i) Ore and Air; Raw materials (ii) Goke and Limestone; From Ore to Iron—The blast furnace; iron into steel—the open hearth furnace; iron into steel—The Bessemer process; iron into steel—Crucible and electric methods; the shaping of hot steel; the properties of steel (British Iron and Steel Federation, 1960) This series of eight booklets of about 25 pages each is exceptionally clearly laid out and is almost self-explanatory. In every case the left-hand page contains three frames taken from the GB film library (25-30 to each booklet) while the appropriate test is set out on the right hand; the test is succinct. The whole series makes a most valuable addition to existing teaching material and the film-presentation and simplicity makes this contribution unique

The activities of the Verein Deutscher Eisenhüttenleute during 1960 (Stahl Eisen, 1961, 81, April 13, 461-497) This report deals, among other topics, with activities of the publication department, of the library, and of the numerous committees (282 refs).

Inside the factory gates: Stahl und Walzwerk Brandenburg Stahl und Walzwerk Brandenburg (Met. Bull., 1961, 49, April 25, 14–15, 28) The steel-melting shop and rolling mills now operating on the site of the former Flick works (dismantled under the Potsdam agreement) at Brandenburg in Eastern Germany near Berlin, and their varied activities and equip-ment are described, with data on labour, wages, and varied subsidiary installations and

non-ferrous output.—s. H.

The Italian steel mission from Assider in Russia. Blast furnaces and coke ovens D. Andreani (Met. Ital., 1961, 53, (3), 106–108) [In Italian] Soviet pig iron production in 1960 was 47 m. t and the 1970 target is 70 m. t. Iron ore reserves amount to 85 000 m. t. The standard size of blast-furnaces is 1513 and 1710 m3. Coke consumption in some blast-furnaces is as low as 600 kg/t, due to careful burden preparation and sintering, maintenance of constant humidity in air blown in, high air preheating temp., high top-pressure and natural gas blown in through the tuyere zone. The operation of one blast-furnace visited is studied in more detail.

Russian steelworks G. Massobrio (Met. Ital., 1961, **53**, (3), 108–110) Visits to Russian steelworks are described. Production targets will be met by: (a) constructing new LD and OH furnaces. Intentions are to construct highcapacity OH furnaces of 550-800 t. Present LD converter size of 50 t will be increased to 100 and possibly 180 t. Production from new lant will be divided equally between LD and plant will be divided equally between LD and OH furnaces. (b) Increasing production from existing OH furnaces (1) by improved scrap preparation (2) use of ore and briquettes of very low SiO<sub>3</sub> content, (3) furnaces will cast into two ladles, doubling furnace output,

(4) using methane rather than mixed gas, (5) developing oxygen lance blowing, (6) more automation and electronic devices

Russian rolling mills and rolling practice  $\mathbf{M}$ . Gatti (Met. Ital., 1961, 53, (3), 110–112) The proportion of rolled steel products produced in proportion of rolled steel products produced in 1958 in USSR was sections and bars 60%, strip and plates 19%, tubes 14%, rods 5%, wheels and axles 2%. A description of normal Russian practice follows. The article concludes with descriptions of two continuous casting plants. The plant at Novo Lipetsk casts slabs 1200×70 from 90 t electric furnaces for the production of magnetic sheets on a Steekel mill. The steel has a yield of 90% from liquid to slab. The other plant, a layout diagram of which is provided, is at Stalino.

Eregli steel projects (Brit. Steel, 1961, 27, March, 88-89) Plans for an integrated steel-works 350 km east of Istanbul on the Asiatic coast of the Black Sea, owned jointly by the Turkish Government and an American consortium, and to be operated by Koppers Co. Inc., with an ultimate capacity of 10<sup>8</sup> metric t

per annum, are outlined.—s. H.-S.

Durgapur-a technical survey. General layout of the works (Iron Coal Trades Rev., 1960, pp.218, 24-26) A blue-print of the layout is provided.—c. v

China's iron and steelworks: the border areas (*Met. Bull.*, 1961, **49**, April 18, i–iv) The growth of Chinese iron and steel output from  $5\times10^6$  t in 1957 to  $18\cdot5\times10^6$  t of steel in 1960 is claimed as primarily due to the phenomenal increase of heavy industry in Manchuria, increase of heavy industry in Manchuria, which is described. Short subsidiary data are also given on the developments now taking place in Inner Mongolia, Sinkiang, Chinghai, and even in Tibet, where the first tap of molten iron in the history of Tibet flowed at Lhasa on Oct. 2, 1960. A summary of various forms of iron, steel, engineering, and electrical activities, in the different provinces (some with heavy Soviet aid) is incorporated in the article.—s.H.-s.

Ferrous developments in the Dnieper area of USSR A. Sanin (Iron Steel Eng., 1961, 38, Feb., 134) A note on the development of the Ukraine iron and steel industry in the Dnieper

The American iron and steel industry G. Grenier (Mines et Min., 1961, May, 281–284) [In French] This article deals with iron ore and blast-furnaces in the USA. A table is given which analyses the types of ore consumed in the steelmaking regions of the USA. Sintered ore has increased from  $13.9 \times 10^6$  t in 1954 to 27.5×106 t in 1959. Comparative coke consumption is given for various countries including the USA. The types of coke used are analysed. Types of US pig iron and slag are analysed and the distribution of production between the various regions is given.

Kaiser steel T. J. Ess (Iron Steel Eng., 1961, 38, Feb., K1-K58) An account of the iron and steelmaking and processing equipment of the Kaiser Steel Fontana plant.

Mexico's iron and steel industry (Met. Bull., 1961, **49**, March 17, i-iv) A brief survey of the principal producing plants, with a review of integrated and semi-integrated works, programmes of expansion, and new projects is presented. An outline map, showing locations of blast furnaces, iron and steelworks, and main iron ore and Mn ore deposits, is appended.

# BLAST-FURNACE PRACTICE AND PRODUCTION OF PIG IRON

Durgapur-A technical survey. Ironmaking plant (Iron Coal Trades Rev., 1960, pp.218, 66-81) The main layout and design of this plant was undertaken by Head Wrightson Iron and Steel Works Engineering Ltd. The ore reception, stocking, and blending, limestone, etc., handling are summarized. The furnace has a diameter of 27 ft and an effective volume of 41370 ft³ and the other details are provided. Gas-cleaning plant, washers, and precipitators are briefly described. The pigcasting plant is also designed and produced by Head Wrightson and consists of two doublestrand pig casting machines and a stocking gantry; the former are served by 90-t 'Kling' ladles with a 'Davit' tilter to pour the metal

from the ladles into the runners; each strand has 292 pig-moulds of 112-120 lb capacity, and the rating for each is 120 t/castings/h, pig cooling time being 5.6 min. Electrical equipment, instrumentation, and the various services are indicated .- c.v

Blast-furnace engineering development D. R. Brown and M. Adamson (JISI, 1961, 199, Oct., 117-127) [This issue].

Quality and applications of Belgian blast furnace cement. I L. Blondiau (Silicates Ind., 1961, 26, March, 141-145) [In French] Aspects dealt with include changes in volume (shrinkage and creep) of blast-furnace cement, chemical resistance, and heat of hydration, main uses of blast-furnace cement in Belgium.

Quality and applications of Belgian blast furnace cements. II L. Blondiau (Silicates Ind., 1961, 26, April, 201–207) [In French] This second article gives illustrations and describes uses of reinforced concrete, prestressed concrete, road building, and large projects such as

dams and sluicegates

Automatic loading from a bunker at the Meggen mine of Sachtleben AG K. Wild (A. Erz. Met., 1960, 13, Dec., 593-597) The design, operation, and costs of automatic wagon loading equipment dealing with a wide size range of iron pyrites and barytes fragments are described

Recent developments in burden preparation French blast-furnaces J. Michard, and P. Dancoisne (JISI, 1961, 199, Oct., 143–148) [This issue].

Improving the distribution of the materials in the stack S. V. Vasil'ev (Metallurg., 1960, (8), 8–10) [In Russian] The arrangement of the the stack S. materials in the stack conditions the gas stream. This arrangement depends to a large extent on the ridge which forms when the right-hand or left-hand skips are emptied into the receiving hopper. Special rakes have been mounted at the Novolipetsk blast-furnaces above the large bell to distribute the charges evenly.

Longer life for blast pipes: heat-resisting steel pipes in modern blast furnace tuyeres (Inco Mond Mag., 1961, (17), 1-3) Using the traditional cast iron or mild steel with blast temp. of ~700-800°, excessive scaling occurred. Cr-Ni steel pipes were introduced experimentally for the Appleby-Frodingham Steel Co. Ltd, and were found to be entirely satisfactory; before their introduction replacements were at the rate of one per month while the Cr-Ni ones lasted a year. These pipes have now been introduced elsewhere, and it has been found that both blast temp, and volumes could be increased. H.R. Crown 1 (22.5%Cr, 11%Ni) is used giving good scaling resistance at 1050° and this is centrifugally cast in one piece by Firth-Vickers Stainless Steels Ltd.

Recent developments in the physical chemistry of the slag/metal processes S. Klemantaski (Iron Coal Traces Rev., 1961, 182, 847-851) A review with 26 references.

Influence of oxides of alkaline earth metals on the distribution of sulphur between iron and iron slag L. A. Shvartsman, I. A. Tomilin, O. V. Travin, and I. A. Popov ('Problems of Metallography and the Physics of Metale', Consultants Bureau, Inc., NY, 1959, 405–417) The distribution of S between the liquid Fe and the simple Fe-slag has been studied, the temp. dependence of the distribution coefficient for S has been found and the thermal effect calculated .- c.v

Distribution of sulphur and phosphorus between iron and acid slag I. A. Tomilin and L. A. Shvartsman ('Problems of Metallography and the Physics of Metals', Consultants Bureau, Inc., NY, 1959, 418-424) The thermal effects of these processes have been determined and it is shown that a sharp decrease in the distributions of the state of the st tion coefficients in comparison to iron slag is due to a change of the entropy term of the free energy. A hypothesis is advanced to explain the development of heat in the solvation of Feions in the silicate slag.—c.v.

An investigation into the desulphurization of pig iron by soda O. V. Tarvin and L. A. Shvartsman ('Problems of Metallography and of the Physics of Metals', Consultants Bureau, Inc., NY, 1959, 424-432) The equation involved is:  $28 + \mathrm{Na_2CO_3} + \mathrm{C} = \mathrm{Na_2S_2} + \mathrm{CO_2} + \mathrm{CO}$  the three products of the reaction being gaseous. Raising the temperature decreases the efficiency of the reaction. The kinetics of the process are studied and the heat of activation has been ascertained

A new method for studying equilibria in the system metal-slag V. F. Surov, O. V. Travin, and L. S. Shvartsman ('Problems of Metallography and the Physics of Metals', Consultants Bureau, Inc., NY, 1959, 433-436) The distribution of P and S between Fe and slags of various compositions is shown.-

The influence of magnesia on the desulphurizing capacity of blast furnace slags V. M. Zudin, N. N. Babarykin, A. L. Galatonov, and I. S. Kulikov (Stat', 1961, (5), 385-391) A report of an extensive series of trials at Magnitogorsk. Desulphurizing capacity varies with basicity, but MgO can replace CaO and is elightly to the contract of the con slightly more able to do so in acid slags. Under normal conditions the actual capacity of MgO is 1·1 to 1·5 times that of CaO.

Reducing the sulphur content of pig iron A. Gimmel'farb (Metallurg, 1960, (5), 6-8) [In Russian] An analysis of the steps taken at five of the most important metallurgical works shows that the struggle against sulphur should be pursued in two directions: An improvement of the desulphurization processes in the blast furnace itself, and evolving methods for desulphurizing after tapping, with slags of basicity of 1-1.05.

Control requirements for blast furnace highpressure operation A. J. Karsten (ISA Proc., 1960, 10, (3), 1-5) The question is asked 'What is the optimum top pressure?' and the article discusses the possibilities of its being 40 lb. At present 4.5, 10, and occasionally 12 lb are used and 20-25 is envisaged in the very near future. However, the main discussion centres round the lower range although it is stated that basically the control will be similar for the 20-25 lb range. The valves required, their position and control, and two operating sequences are described while a third is suggested which uses the 'normal' control system automatically, the 'emergency' butterfly valve being operated manually from a 'High-low water level alarm'.

Differential pressure control applied to the blast furnace stock column O. J. Leone (ISA Proc., 1960, 10, (6), 1-11) A pressure-drop control method is applied to the blast-furnace stock column so as to overcome certain operating limitations. This is discussed and several approaches to the evaluation of the selected results and operations are examined.

Fuel-oil injection in a blast-furnace P. Hazard (JISI, 1961, 199, Oct., 128-133) [This

Means of increasing the output of a given blast furnace plant H. P. Weitzer (Berg. Hütten. Monatsh., 1960, 105, 256-261) Experiments carried out on six blast-furnaces show that increased output can be achieved by efficient preparation of the charge, by keeping the moisture content of the blast constant and by oxygen additions to the blast.

Blast-furnace performance with injection at the tuyeres J. M. Ridgion (JISI, 1961, 199, Oct., 135-143) [This issue].

Significance of experimental operations to industrial blast-furnace practice M. B. Royer and W. M. Mahan (US Bur. Mines Rep. Invest. 5766, 1961, pp.8) A report on the operation of the Federal Bureau of Mines experimental blast-furnace at Bruceton, Pa., near Pittsburgh, from 1955 to 1957, with comparative results of blast-furnace operations on hard sinter and Mesabi burdens, is presented.

A search for conditions for faster and more economical blast-furnace operation A. A. Fofanov (Stal', 1961, (5), 402-403) A note from the Ural, Sci. Research Inst. In the smelting of V pig iron the effectiveness of screening out fines below 5 mm from the sinter was confirmed also injecting oil, lowering the basicity of Ti slags, and raising Si content. Pretreatment in the ladle before transfer to the converter was also an advantage.

The importance of the sintering process in the production of pig iron H. Wendeborn (Metall. Gesellschaft, 1959, (1), 3-12) The development of iron ore sintering is reviewed and the effect of sintered ore on blast-furnace operation is discussed. Sintering techniques and installations are described. Future tendencies are indicated (18 refs).-R.P.

Errors in the control of the gas stream and in the distribution of the materials in the stack A. N. Chechuro and I. L. Kolesnik (*Metallurg*, 1960, (8), 7-8) [In Russian] An analysis has shown that the lowest temp. of the peripheral gas occurs where the flow of gases and of materials attains a maximum intensity and the highest temp. occurs under opposite circumstances. This is a contradiction to the accepted theory and results in considerable errors

Some questions regarding blast furnace production with natural gas fuel M. A. Shapovalov (Metallurg, 1960, (8), 4-6) [In Russian] Experience shows that the greatest reduction potential is obtained. tial is achieved when the ratio  $(CO_2+H_2)/(CO_2+H_2O)$  in the stack is at a minimum, equal to the equilibrium condition. Natural gas as fuel reduces coke consumption but reduces the gas dynamics of the furnace by increasing the gas consumption per unit of coke. A decrease in direct reduction and a lowering of the temp. resulting from the use of this gas, makes it possible to melt a low-silicon pig iron containing 0.2-0.3%Si with acid slags having a ratio (CaO+MgO):SiO<sub>2</sub> of about unity and a further desulphurization after tapping

The behaviour of minette sinter in the blast furnace R. Sandhöfer and O. Becker (Stahl Eisen, 1961, 81, April 13, 501-503) Special working conditions such as rather low blastfurnaces and short transport between sinter plant and blast-furnace allow the smelting of a spongy, highly oxidized sinter of small lump size at Röchling Werke Völklingen. The blastfurnace works perfectly, although the amount of flue dust is considerably higher than with hard sinter of large lump size. But the savings in coke consumption are material.—T.G.

Investigation of the effect of the oxidizing zone on gas distribution in the blast furnace A. A. Fofanov and L. Ya. Gavrilyuk (Stal', 1961, (5), 402) A note from the Ural Scientific Res. Inst. Throat to hearth dia. is considered and furnace lines with two rows of tuyeres are proposed. Automation controlled by gas composition is also advocated.

Improvement of blast-furnace plant auxiliary equipment I. I. Korobov, V. I. Surovov, K. I. Kotov, and A. G. Efimenko (Stal', 1961, (5), 397-402) Improvements in the wagon tippler and stockyard equipment, granulating pond, and casting machine are described.

Experiences gained with a blast furnace gas turbo-blower in the foundry at Donawitz A. Vacek (Berg. Hütten. Monatsh., 1960, 105, Nov., 250-256) The suitability of various blowers for a blast-furnace of 800 t/day output are discussed and compared. A blast-furnace gas turbo-blower is recommended. The layout, operation, and economics of the plant are described.—R.P.

Properties and uses of blast furnace gas J. Szczeniowski (Blast Furnace Gas, IRSID, Les Cahiers du Cessid, 1959, (4), pp.26) The properties of blast-furnace gas are reviewed, and its uses as fuel are described. Problems connected with the future applications of blast-furnace gas are discussed—increased consumption, reduced combustion, temp., etc.

Iron in the electric furnace in Italy P. Nigri and G. Moga (Met. Ital., 1962, 53, (4), 149-156) [In Italian] In Italy the electric furnace is established as an ironmaking process because of the modest tonnage requirements, low capital investment, possibility of using varied and low-grade native ores. High ash native anthracite and lignite can be used. There is flexibility in quick and easy starting up and hence adaptability to market requirements and power fluctuations. Better handling of sulphur part is vaporized as silicon sulphide. Less dust loss and easier recovery. However the high cost of electric power and its seasonal availability restricts the use of electric furn-

Orcarb process provides high prereduction in production of pig iron W. M. Jordan (Indust. Heat., 1960, 27, Sept., 1800–1808, 1812) Successful testing is reported for the process which involves agglomeration of ore with carbon and flux, reduction in a rotary kiln, and electric furnace smelting. There is > 80% deoxidation before smelting. Very fine material, e.g. precipitator dust, can be pelletized. Capital costs are low compared with the conventional process, and charges for Zn and ferroalloy

process, and charges for Zn and ferroalloy production can also be prepared.—K.E.J.

Electric smelting titaniferous magnetite ore, Iron Mountain, Wyoming H. C. Fuller and V. E. Edlund (US Bur. Mines Rep. Invest. 5776, 1961, pp.11) Tests to determine the feasibility of smelting this ore, containing about 20% titanium dioxide (TiO<sub>2</sub>) in an electric-arc furnace to produce pig iron are reported and results are discussed.—s.H.-S.

The mixer: technological study G. Gros-

The mixer: technological study G. Grosdemange (The Thomas Steelworks, IRSID, Les Cahiers du Cessid, 1959, (5), pp.29) The uses, classification, construction, lining, and heating of the mixer are described (11 refs).

Shock loading to produce fine grain structure E. G. Zukas and R. G. McQueen (*Trans. Met. Soc. AIME*, 1961, **221**, April, 412–413) The production of an isotropic fine-grained ingot iron in small quantities is described; with larger samples uniformity of grain is not possible although impulsive loading followed by suitable recrystallization treatment gives interesting results. Photomicrographs (×100) of the microstructure before and after shock loading are shown .-- C. V.

#### PROPERTIES, TREATMENT AND USE OF SLAG

Physico-chemical properties of titanium-magnesia slags with a high alumina content V. Ya. Miller and N. M. Babushkin (Stal', 1961, Y. Ya. Miller and N. M. Babushkin (Stal', 1961, (5), 391–397) A study at the Ural Institute on the blast-furnace smelting of sinter made from a highly concentrated Ti-magnetite ore is reported. Viscosity was measured as well as sulphur uptake and an optimum basicity and MgO content as well as a maximum for Al<sub>2</sub>O<sub>3</sub> were established. were established.

Melting relations of magnesium oxide-iron oxide mixtures in air B. Phillips, S. Somiya, and A. Muan (J. Am. Ceram. Soc., 1961, 44, April, 167–169) A quenching technique is used this study in the temp. range 1415-1800° Magnesio-wüstite and magnesio-ferrite are the only crystalline phases present, the latter melting incongruently to the former + liquid at 1713 $\pm$ 5°. The liquid contains  $\sim$ 92% iron oxide calculated as Fe<sub>2</sub>O<sub>3</sub>.—c.v.

Some calcium-iron-oxygen compounds P. B. Braun and W. Kwestroo (Philips Res. Rep., 1960, 15, Aug., 394–397) Three new Ca-oxide-1960, 15, Aug., 394-391) three new Ca-oxideron compounds are stabilized by the addition of small amounts of a third component. Ca<sub>4</sub>Fe<sub>14</sub>O<sub>25</sub> hexagonal ( $R\bar{3}c$ ) with a=6.0Å and c=95.0 Å, stabilized by Y<sup>3+</sup> ferrimagnetic, preferential plane of magnetization. Ca4Fe14O25 hexagonal  $(P\overline{3}c)$  with  $a=6\cdot 0$  Å and  $c=31\cdot 6$  Å stabilized by Mg<sup>2+</sup>, Ca<sub>4</sub>Fe<sup>2+</sup>Fe<sup>8+</sup><sub>18</sub>O<sub>33</sub>hexagonal  $(R\overline{3}c)$  with  $a=6\cdot 0$  Å and  $c=62\cdot 3$  Å also stabilized by Mg<sup>2+</sup> ions. Ferrimagnetic, preferential plane of magnetization. Magnetic properties and X-ray data are given.—c.v.

# PRODUCTION OF STEEL

Possible lines of development in iron metallurgy S. Eketorp (Tekn Tidsk., 1961, 91 March 10, 213-217) Steel production by differ ent processes is graphically presented with comment 1800-1960. Modern processes with different furnaces when tabulated show that the OH is not ideal. That ideal exists today on paper only. Ore reduction is by several methods, including the use of oxygen as in modern production of steel. In future developments of continuous processes a standard composition of raw material will be of great importance.

Some considerations on the problem of scrap P. Galler (Rev. Univ. Min., 1960, 16, Sept., 362-369) A discussion of the scrap problem in Belgium, in relation to the Common Market. Sources and utilization of scrap are discussed, and the effect on the scrap position of the introduction of large-capacity electric arc furnaces is considered. Tables showing production and consumption of scrap in countries are given at the end of the article.

Scrap is cut and compacted in huge hydraulic shear Sternoff Metals Corp. (Steel, 1961, 148, May 1, 72) The operation of 1150 t capacity shears installed at scrapyards at Tacoma, Wash., South Beloit, Ill., and Sharpsburg, Pa., is briefly described with data on smaller units. Dependable oxygen supplies T. A. Donegan (Iron Steel Eng., 1960, 37, Dec., 119-122) A review of the features of on-site oxygen producing equipment.

High-strength austenitic stainless steels K. J. Irvine, D. T. Llewellyn, and F. B. Pickering (JISI, 1961, 199, Oct., 153-175)

Fuel and energy required for steelmaking by the VLN converter process G. G. Fletcher and R. A. Pullen (J. Inst. Fuel, 1961, 34, Feb., 46–52) The oxygen-steam bottom-blown basic converter process (VLN=very low nitrogen), produces deep-drawing quality steels with 0.001% N. To refine 1.3% P hot metal, the O. and steam consumptions are 2000 ft<sup>3</sup> and 2400 ft<sup>3</sup> per ingot t respectively. No form of externally supplied fuel is used in the process. The rate of steel production is high, 110 ingot t/h/converter, and each converter has a metal-

The Kaldo process at Sollac R. Colmant, G. Decamps, and P. Rocquet (Rev. Mét., 1961, 58, Jan., 39-43) The equipment of the Kaldo plant installed in 1960, its operation, and results obtained are described. Extra mild steel for deep drawing is produced from Lorraine phosphoric iron.

Rotor steelmaking furnace minimizes charged scrap (Steel, 1961, 148, March 13, 130) The functions and operation of Demag rotor furnaces, in use by the S. African Iron and Steel Industrial Corp. Ltd, in turning out 100 t heats of steel equal to that made in basic OH furnaces, are described .- s. H.-S.

Steelmaking (Union Carbide Metals Rev., 1960, 1, (4), 4–8) A brief review. It is considered that a 200-t furnace can make heats almost as fast as the smaller ones which may make the t/h output in excess of this figure. The differences and advantages of the OH and basicoxygen furnaces are summarized.-c.v.

On the quality of hanger tabs in suspended stones H. Longin (Radex Runds., 1961, April, 561-565) The causes of the tearing off of hanger tabs from suspended roofs in OH furnaces were discussed. It was found that the steel type 18/8 normally used for this purpose is attacked by the S in the furnace dust, by reaction of the S with the nickel in the steel. The sulphide eutectic formed has a low melting point, 645°C, and thus causes failure of the hanger tabs. If a new type of steel were used, in which the Ni content was lowered to 4%, the Cr content was increased to 25% and the Si content was also increased, the failures disappeared.-M.L.

Starting up the operation of a 500 ton open hearth furnace on coke-oven gas and oil I Dikshtein, Ya. A. Goncharevskii, K. A. Zuts, V. G. Antipin, M. G. Kozhanov, Yu. A. Zarshitskii, and A. M. Kulakov (Stal', 1961, (3), 210–214) The management of a singleuptake furnace on the scrap-ore process of which details are given is described. Troubles encountered in the early stages and the solutions found are reported. Various other possible improvements are noted.

Behaviour of the free gas jet in air J. Maatsch (Techn. Mitt. Krupp., 1961, 19, March, 17-31) Hydrodynamic and gas-dynamic laws for the flow of compressed gases from a nozzle are derived, for the formation of a free O<sub>2</sub> jet in air. Simple formulae and graphical illustrations were developed for the calculation of the magnitudes which describe the jet, thus enabling prediction of the amount of gas and the chemical composition of the jet as a function of the distance from the nozzle, knowing only the pressure of the compressed gas and the geometrical data of the nozzle. The effect of various nozzle shapes on the characteristics of the jet were also studied (16 refs).—M.L.

The enrichment with oxygen of the flame in basic open-hearth furnaces of large capacity.

11. D. Milcoveanu (Met. Constr. Masini, 1960, 12, (11), 971-977) In order to determine the effects of the higher flame temp. in the basic OH furnace (due to enrichment with O2 of the combustion air) upon the charge increases and heat time shortening, in the cases of the two processes, scrap-liquid pig iron and solid pig-iron-scrap, the heat exchange with the charge was calculated by means of the Bolzmann formula. The resulting economic and technical advantages as well as the technological limitations in the present installations are summarized .-

Use of atomized fuel oil in metallurgical furnaces N. S. Zheltov and A. D. Akimenko (Stal', 1961, (2), 185–188) Use in OH furnaces and soaking pits is described. The method makes special drying of the oil unnecessary, though no more moisture than cannot be avoided should be allowed to enter the fuel oil in transport and use.

A computer and a melting shop P. Beynon

(JISI, 1961, 199, Oct., 181–183) [This issue].
Melting of the charge in open-hearth furnaces investigated with different methods of utilization of oxygen K. M. Trubetskov, V. N. Kornfel'd, E. A. Grekov, A. O. Voitov, L. S. Shteinberg, and G. A. Lomtatidze (Stal', 1961, (3), 216-222) Using a tracer method, it was found that the mean rate of melting of scrap is practically the same whether the blast is enriched or the bath is oxygen blown, though with oxygen blowing, carbon content is reduced. Data on heat absorption by the bath are included.

The control of tap temperature in open-hearth furnaces M. L. Hasek, S. W. Balbi, C. H. M. Braga, E. Grees, E. P. Souza, L. V. Silva, and O. L. Barbosa (Bol. ABM, 1961, 17, Jan., 59-70) [In Portuguese] A statistical analysis of the results of control of tap temp. by immersion pyrometer is reported.

The use of radioactive isotopes in the inspection of the technology of the continuous casting process C. Varga and J. Fodor (Second United Nations Internt. Conf. on Peaceful Uses of Atomic Energy, 1958, June, preprint, pp.7) Methods of locating the junction of solid and liquid in the crystallizing zone within the mould are considered. A W ball carrying 60Co was used. An autoradiographic method was also developed.

The 'Weybridge' multiple mould process for continuous casting of tonnage steel J. Savage and J. Pearson (Iron Coal Trades Rev., 1961, 182, April 7, 725-728) The process is described in some detail. The advantages are the reduction in number of casting strands, saving in cost and operational reliability. This process is now in operation using a reciprocating mould cycle for casting low-C steel on a large-scale pilot machine of the Centre National de Recherches Métallurgiques at Charleroi. A mould is also under construction for the production of 5in blooms and it is expected to obtain a production rate of 35 t/h. Application to high alloy and special steels is also being investigated .-- c. v

A new reciprocating mould cycle to improve surface quality of continuously cast steel J. Savage (Iron Coal Trades Rev., 1961, 182, April 14, 787-795) Steel cast continuously at relatively high speeds is often characterized by the presence of fine lateral surface markings. Although these do not result in difficulties in rolling, they almost certainly produce mechanical weakness of the ingot shell below the mould thus preventing the attainment of optimum withdrawal speeds. The causes of these and their prevention are discussed.—c.v.

The application of ultrasonic energy to ingot solidification. I D. H. Lane, J. W. Cunningham, and W. A. Tiller (Trans. Met. Soc. AIME, 1960, 218, Dec., 985-990) The effect of ultrasonic vibrations on ingot solidification has been considered both theoretically and mentally, the theoretical section elucidating the mechanisms by which the ultrasonic vibrations might refine the ingot structure, and the experimental section describing an efficient means of introducing the ultrasonic vibrations to the freezing interface. The application of this technique to the consumable-electrode are melting process shows that the columnar mode of freezing may be effectively suppressed, yielding an ingot structure consisting predominantly of equiaxial grains. Results support the contention that the ultrasonic vibrations increase the nucleation frequency in the layer of liquid adjacent to the freezing interface.

The application of ultrasonic energy to ingot solidification, II D. H. Lane and W. A. Tiller (Trans. Met. Soc. AIME, 1960, 218, Dec., 991-994) A simple zone melting technique for investigating the effect of ultrasonic irradiation upon ingot solidification is described. The

effect of ultrasonic power level, freezing velocity, constant or variable frequency, direction of irradiation, and transducer-coupling bar joint upon the grain size of type 316 stainless steel have been investigated. The results of the study support the postulate that the ultrasonic vibrations increase the nucleation probability in the layer of liquid adjacent to the freezing interface .- s. H.- s.

# PRODUCTION OF FERRO-ALLOYS

Electric smelting of Montana chromite concentrates W. L. Hunter and L. H. Banning (US Bur. Mines Rep. Invest. 5775, 1961, pp.30) A report on research conducted to obtain information on the feasibility of producing Fe-Cr from the concentrates from the Mouat deposit in the Stillwater complex, the largest American domestic reserve, is presented and discussed .- D.H.-s.

The production of ferro-nickel by the Ugine process in the U.S.A. (J. Four. Elect., 1961, 66, March, 85-88) This article describes produc-tion of Fe-Ni at the Hanna Nickel Smelting Co. where an extension of the Ugine-Perrin process is used. Aspects dealt with include extraction and drying of the ore, calcination and reduction of the ore and the Ugine Perrin

refining reduction process

Advanced production of silicon ferroalloys Yu. S. Maksimov and Ya. S. Shehedrovitskii (Metallurg, 1960, (6), 34-35) [In Russian] In June 1959 an interfactory school has been opened for the study of advanced methods of silicon ferroalloy production. This is sponsored by seven metallurgical plants and it is hoped that in time this school will contribute to an improvement of production.

Ferro-silicon and silicon metal H. Willners and K. A. Ottander (Jernkontorets Tekn. Rad., 1953, 17, (190), 787-817) Raw material from Swedish deposits of quartz and normally, light scrap iron is not treated in a blast-furnace but in an electric furnace in the manufacture of Fe-Si. Statistics of production, consumption, and commercial data appear in tables and graphs with notes in the text. Physical characteristics, diagram of condition (from Metals Handbook), and other technical data are followed by analysis in some detail: (1) Swedish, (2) after Matuschka and Cless, and (3) US standards with numerous tables and graphs. The uses are described at some length. An order in council regulating transport and storage is given in full (40 refs).

Smelting ferrosilicon in a closed electric furnace G. Sh. Mikeladze, E. M. Nadiradze, Sh. M. Bezarashvili, G. A. Dgebuadze, R. N. Tskhvediani, D. S. Chikashua, and A. I. Metrevili (Stal', 1961, (5), 419–422) Use of a closed furnace on an experimental scale in smelting  $20\% {\rm Fe-Si}$  saved materials and power, and the flue gas formed was over 90 %CO.

# FOUNDRY PRACTICE

Problems of the foundry industry P. N. Ghosh (Iron Steel Rev., 1961, 4, March, 25-26) The shortage of raw materials in the Indian foundry industry is discussed; this is aggravated by the problem of transport. In order to compete successfully against foreign products, the present high price of pig iron must be lowered.

New graphical representation of the relationship between the mechanical properties and chemical composition of castings A. Königer and W. D. Rörke (Giesserei Techn. -Wiss. Beihefte, 1961, 13, April, 97-100) A nomogram for east iron has been prepared which correlated the state of the control of the contro ates hardness, tensile strength, chemical composition, and cooling rate, and gives the structure appearing in the 30 mm specimen rod

(16 refs).—M.L. Size tolerances and over thicknesses in machining mass-produced non-alloy grey iron castings Fiocre (Usine Nouv., 1961, Jan. Supplement, 75-77) A summary of a paper designed to give a guide to the production of grey iron castings which satisfy the designer and are within the scope of the foundry.

Tin as a ladle addition in the casting of iron:
a foundry's experience R. M. Macintosh (Tin,
1961, no.51, 1-3) The effect of adding tin to the
ladleful, either as a cast disc or as two such
discs is described. Success in controlling hardness of castings by this method is claimed.

Picture types and their modifications in the art of hearth-plate casting S. Theisen (Stahl Eisen, 1961, 81, March 30, 401-404) A comparison is made of reliefs on cast iron hearth and oven plates produced in the 16th and 17th centuries, showing that the same motif has been used by more than one craftsman,—T.G.

Reports on visits to malleable and spheroidal iron foundries in USA and Europe G. Gallo (Fond. Ital., 1961, 10, (3), 79–82) [In Italian] Methods of producing malleable and spheroidal iron in Europe and USA are contrasted. The advantages of the shell moulding process for moulding and pouring castings are described. Finally the use of automatic moulding mach-

ines to increase productivity is dealt with.

Iscor's new foundry (J. S. Afr. I. S. Indust.
Corp., 1959, Sept., 2-5) The new foundry at the
Pretoria works of the S. Afr. Iron and Steel Industrial Corp. Ltd., with details and illustra-tions of its mechanical equipment and operation, is briefly described.—s. H.-s.

Durgapur—A technical survey. Iron and steel foundry (Iron Coal Trades Rev., pp.218, 165-172) Davy and United Engineering Co. Ltd, together with Campbell Gifford and Morton Ltd have been responsible for the design and layout. The main regular production is cast iron ingot moulds, 20000 t/year, and these will be suitable for casting ingots up to 7 t in weight for rolling or up to 4 t for wheel forging. In addition a further 5000 t of various iron castings will be produced together with a small quantity of non-ferrous castings; the layout is described.—c.v.

Studies of the design of steel castings and Studies of the design of steel castings and steel weldments as related to methods of their manufacture H. R. Nara, D. K. Wright jum., and C. W. Briggs (Trans ASME, 'B', J. Eng. Ind., 1961, 83, (1), Feb., 73-91) Joining sections in the form of L-sections and box sections produced designs by commercial methods using steel castings and weldments, by welding rolled steel pieces. A number of detailed conclusions is given and discussed.

What the casting designer and buyer expect of the foundryman T. O. Kuivinen ( $Trans.\ AFS$ , 1959, 67, 715–717) It would be advantageous if the designer had greater knowledge the foundryman's problems and vice versa. This article briefly reviews this problem giving examples of the problems that arise from this lack of mutual understanding.

The use of natural gas in foundries A. Pointeau (Mét. Constr. Mécan., 1961, 93, March, 241, 243-245, 247) The use by the Mousserolles Foundries near Bayonne of natural gas from the Lacq field, some 70 km distant, is described, with details of its application in their malleable iron annealing furnaces, galvanizing and bronze smelting furnaces, core ovens, sand driers, etc. Particulars of apparatus, control devices, and temp. operated are presented and some of the advantages dis-

How town gas is being used at Swindon Locomotive Works. 2 (Ind. Gas., 1961, 24, Feb., 18-24) The uses of gas in the foundry and for heat-treatment, and the types of furnace employed, are described.

Significance of reported chemical analysis of cast iron D. E. Krause (Trans. AFS, 1959, 67, 705-714) Chemical analysis data reported by more than 30 laboratories for 40 samples of cast iron over a 15-year-period are examined and indicate that the limits for accuracy and reproducibility are greater than commonly assumed. Reproducibility of analysis does not necessarily indicate accuracy and this can only be determined by submitting the same sample to at least six laboratories. These views should be taken into account when evaluating the relationship between chemical composition and mechanical and physical properties. The causes of some of the variations in accuracy of analyses are explained.—c.v

Time-temperature effects of cooling, solidifi-Time-temperature effects of cooling, solidification and transformation in castings W. Patterson and W. Koppe (IGK Kongress-Vorträge, 27th International Foundry Congress, Zürich, 1960, 25-46) [In German] A general equation describing the loss of heat from the casting to the mould in sand casting for constant or falling temps., and transforma-tion is derived and discussed. In the second

part of the paper the validity of the equation is shown experimentally down to low temps. A method is shown for calculating cooling curves of infinite plates and hence of the correction factors for simple bodies. The influence of analysis on time-temp. effects of cooling, solidification, and transformation of cast iron melts with 2-4% and 0.5-3%Si was examined.

Efficiency in production and use of man-power in the foundry (Fonderia, 1961, 10, Jan 37-41) [In Italian] A theoretical analysis.

New automatic moulding shops H. Bergmann (Giesserei, 1960, 47, Sept. 8, 487–492) Three types of automatic plants are described in detail, and their productivity discussed.

Modern tendencies of development in the mechanization of foundry plant W. Gesell (Met. Elect., 1961, 25, March, 87-100) Modern methods of layout, material handling, and equipment including the use of electromagnetic cranes for mixing of car lots, the use of special moulding machines, and other operational data are discussed.—s.H.-s.

Mechanical handling in the manufacture of castings J. A. Edwards (*Iron Steel*, 1961, **34**, March, 96–98) This versatile conveyor system has been installed at the Scullin Steel Co., St Louis, Mo. It consists in a circuitous free track of 900 ft which connects all stations of the processing operations and three powered conveyors that move the castings along the free track from annealing to storage, from storage to shot-blast area, and from here to the unloading area or, if necessary, back to the shot-blast chamber. The essentials are described.

Further development of the Bührer moulding and casting plant W. Götz (IGK Kongress Vorträge, 27th International Foundry Congress, Zürich, 1960, 207–222) [In German] The development of three automatic 'Bührer' moulding and easting plants, by Georg Fischer AG of Schaffhausen is described, i.e. the proto-type plant at Schaffhausen, the plant at Mettmann, and the plant for the malleable cast iron plant for Singen am Hohentwiel.

Assessment of the water-cooled cupola Modern Equipment Co. (Refract. J., 1961, 37, March, 93-94, and 78) Results of experience in three American and one Canadian installations of this type of equipment are presented and assessed .- s.H.-s.

Hot-blast cupola furnaces W. Bongartz (Koh. Lapok-Öntöde, 1960, 11, Oct., 228-234) The construction and operation of acid and basic lined, hot-blast cupola furnaces, made by the 'Gesellschaft für Hüttenwerke Anlager Düsseldorf' are described by the author. - P.K

Latest findings for the construction and operation of hot blast cupolas S. Tunder and L. Höhla (Engineer Foundryman, 1961, 26, Jan., 17-28) A survey, based on the experience of the past ten years, covering the metallurgy of the hot blast cupola, cupola design, the basic hot blast cupola, the shaking ladle, cupola blast preheaters, instrumentation, charging equipment, and applications, is presented. A discussion follows. S.H.-S

Melting in the hot blast cupola A. C. Buesing (Foundry, 1960, 88, Nov., 96-99) The performances of hot blast and standard cold blast cupolas are compared and the advantages and applications of hot blast are discussed. The water-cooled cupola and the inclined watercooled cupola are also considered .- s.H.-s.

Hot blast cupola melting fundamentals A. C. Buesing (Castings, 1961, 7, Jan., 9-20) After a preliminary discussion on the use of cold blast, the author surveys various aspects of the operation of hot blast and its applications to different types of cupola, concluding with the role of protruding water-cooled tuyeres and the use of high-temp. hot blast.— s.H.-s. Determination of the linear rate of combus-

tion in the combustion zone of the cupola C. Podrzucki (IGK Kongress Vorträge, 27th International Foundry Congress, Zürich, 1960, 107–122) [In French] An expression is derived for the linear velocity of the combustion of coke, and formulas are obtained, from theoretical and practical considerations (combustion tests in an experimental shaft furnace), defining the relationship between linear velocity of combustion and the velocity of gases flowing through the coke, O<sub>2</sub> concentration in the blast, blast temp., and average temp. in the combustion zone (39 refs).

Acid cupola melting for ductile iron H. E. Henderson ( $Trans\ AFS$ , 1959, **67**, 661–668) Carbide desulphurizing by the addition of 1.0-1.5% CaC2 is discussed; the efficiency increases 1.5%CaC<sub>2</sub> is discussed; the efficiency increases rapidly with rise in temp. 2950°F being the optimum. The charge, 2000 lb is made up of 500 lb low-carbon, low Mn, pig iron, 700 lb selected steel scrap as free of carbide stabilizing elements and tramp elements as possible, and 800 lb ductile iron return scrap, 1.02%Si, and 8.59%Wh, 0.054% P. and 2.05% cotal C and 0.52%Mn, 0.054%P, and 2.05% total C, and the method of production and control of composition is described. Further work in basic cupola melting is described the charge being 60% steel scrap, 30% ductile iron return and cast scrap, and 10% low Mn silvery pig iron. The coke charge was 15% low-C pick-up coke in one case and 13% in another. The flux charge was 10% dolomite and 2% fluorspar and air rate was 900 lb/min blast temp. varying from 600-800°F. Basicity increases as the Si-content of the metal decreases S is not reduced to the desired level of <0.02%, total C is > than the desired level of <3.75% and Si loss is ~40% of the charged Si. The melting rates are three-quarters those of the acid melt ing, 22½ t/h as compared with 30 t/h.—c.v.

Some results of investigations with an 'MBC' cupola I. R. Doat, H. Doutreloux, and H. de Rijcker (IGK Kongress Vorträge, 27th International Foundry Congress, Zürich, 1960, 7-17) [In French] Measurements and observa-tions made on a hot blast MBC (Metallurgical Blast Cupola) with a melting rate of 10 t/h are reported, particular attention being paid to the tuyere zone. It is concluded that it is well worth while economically to increase coke consumption to obtain the high temps. possible in cupola, thereby diminishing Fe, Mn, and Si losses.

The mechanical behaviour of grey iron. Definition of a 'massivity invariant' index of quality of the material R. Namur (Fond. Belge, 1961, 31, Feb., 33-44) The existence of a mechanical invariant that characterizes a given grey iron as a material is claimed and established, which is not dependent on the dimensions of the test-piece. This invariant serves as a 'quality index', and as a basis in accepting or standardizing grey iron.—s.H.-s.

The workability of grey iron (Fonderia, 1961, 10, March, 105–109) [In Italian] The influence of various constituents of grey iron and the effect of melting operations in the cupola furnace on its workability are outlined. Two tests of workability, the Brinell hardness test and the testing of standard samples hourly are described briefly. Finally the influence of cool-ing rate is dealt with.

The problem of evaluating grey cast irons and the role of secondary grain structure A. Collaud (IGK Kongress Vorträge, 27th Interconsider (IGK Kongress Vorträge, 27th International Foundry Congress, Zürich, 1960, 85–106) [In French] In examining factors influencing the 'quality index' in the equation:  $\alpha = \frac{\sigma B}{F_c A} \cdot 10^{-5} \text{ established by } 10^{-5}$ 

 $\frac{\sigma B}{E_0 \mathcal{J}}$ .  $10^{-5}$  established by the author, two series of grey cast irons were studied. It was found with correct melting conditions that  $\alpha = 1.05$  approximately. This value can be increased by the addition of certain inoculants. The resulting improvement can be attributed to the increased ductility and tenacity of the matrix. This was then considered as a bivariant system, and experiments were carried out by which increasing ferritization was obtained by annealing at different temp. This was found to decrease α, and it was also found that increase in a corresponded to increased impact resistance.

Properties of grey and ductile irons J. F. Wallace (Metals Eng. Quart., 1961, 1, Feb., 12-23) The influence of the different forms of flake graphite in these irons and their matrices on strength, ductility, and stress-strain characteristics is described. The standard method of classifying these irons is summarized and the marked effect of the graphite shape on the notch sensitivity and damping capacity is discussed. Matrix structure and graphitic form have considerable influence on wear resistance and on the thermal and electrical resistance and on the thermal and electrical conductivity of these irons; this is explained (29 refs).-

Effects of copper on grey irons (Fonderia,

1961, 10, Feb., 49-57) [In Italian] Additions of copper to grey irons prevent the formation of ledeburite in the thinner sections and the formation of free ferrite in the large sections of the casting. Copper results in a very uniform structure with no hard or soft points and has a very beneficial effect on hardness and mechanical properties. This article discusses the effects from a practical as well as a theoretical point of viev

Molybdenum cast iron: new uses (Mét. Constr. Mécan., 1961, 93, March, 191, 192, 195–197, 199, 201–202) The effect of Mo on the tensile and impact strength of cast iron is discussed with various metallographic considerations. The properties and uses of grey, white, and malleable pig iron are presented and analysed .-- s.H.-s

Iron offers low residuals Quebec Iron and Titanium Corp. (Steel, 1961, 148, March 13, 122) A relatively new ferrous material, Sorel metal, a product of a Canadian direct reduc-tion process, with low-alloy content, offering certain manufacturing advantages in the production of nodular or ductile cast iron, is described -S.H.-S

Ductile metal M. Paris and J. Driancourt (Technique Mod., 1961, 53, March, 104–106) Ductile metal, or spheroidal graphite metal, is obtained by adding Ce, Ca, or more generally Mg, giving excellent mechanical properties, ease of casting, and resistance to corrosion. Its chief applications are listed and briefly dishearing . P. H P.

Factors influencing the inoculation of cast iron J. V. Dawson ( $BCIRA\ J$ ., 1961, 9, March, 199–236) A detailed review. The conclusions are presented for flake graphite and nodular irons separately and jointly.-c.v.

Research digs deeper into annealed nodular iron R. C. Bates (Iron Age, 1960, 186, Nov. 17, 144–145) Research into the heat-treatment of nodular cast iron is reported. A study of the question whether enough carbon can be diffused into the matrix from the graphite nodular during austenitizing, and a comparison of the response of the annealed and as-cast grades to both quench hardening and normalizing heattreatments was made, austenitizing tembeing held throughout the study at 1600°F 15°F, times ranging from 2 min to 1 h. Results are discussed .- s.H.-s.

are discussed.—S.H.-S.

Alloyed spheroidal graphitic iron E. E.
Farafonov and L. P. Gorushkina (Bergakademie, 1961, 13, Feb., 106–107; from Lit.
Proizv., 1960, (7), 24–26) The mechanical properties of a spheroidal graphite iron, alloyed with Cu, Cr, Ni, and Mo were studied, varying the proportions of the alloying metals. A remarkable refining of the pearlite was observed. The effects of the various alloying elements are summarized — M. I. elements are summarized .- M.L.

Some investigations on cerium-treated cast iron M. Homma, A. Minato, H. Meguro, and Y. Abe (Sci. Rep. Res. Inst., Tohoku Univ., 1960, 12A, Dec., 500-510) The effects of the addition of Ce on the macro- and microstructure of hypoeutectic and eutectic cast iron have been investigated and further, some experiments were carried out to produce the high strength and rapid-malleable cast iron high in Si by the addition of Ce. Results of tests are given .- C.F.C.

Alloys 'VL55' and 'VL55(M)' Union Carbide Ltd (Alloys Met. Rev., 1961, 2, March, 11-12) The alloys, their properties, and methods of application to S.G. iron production are described.—s.H.-s.

Foundrymen quick to adopt new ductile iron test (Mod. Castings, 1961, 39, March, 37-39) A test procedure developed by the AFS for determining if nodular iron had been successfully inoculated with Mg alloy, is described. The success that it has had in production in five foundries is stressed; all five now use the test in standard production

The effect of aluminium on the mechanical properties of malleable iron E. Fülöp (Koh. Lapok-Öntöde, 1960, 11, Sept., 203–213; Oct., 235-240) By promoting deoxidation and desulphurization, and accelerating graphite formation, added Al decreases the time of malleablizing, and improves the mechanical properties of malleable iron. Addition of Al to the cupola furnace results in a lower strength

but in a higher elongation of iron than addi-

tion into the ladle.—P.K.

Control of foundry steelmaking J. Blackburn (Found. Trade J., 1961, 110, Feb. 23, 231-238) A short general review of all stages in the foundry steel processes, with tests.—c.v.

Rules for the designing and proportioning of steel castings G. Barchiesi (Fonderia, 1961, 10, Feb., 59-64) [In Italian] Aspects dealt with include feeding of the casting, use of cooling devices, and casting techniques amply illustrated by diagrams.

The use of high strength steel castings in aircraft construction H. Tauscher and H. Fleischer (Neue Hütte, 1961, 6, March, 151–156) Development, historical evolution, weldability, and susceptibility to heat-treatment of high-strength steel castings are described. Several materials are tested and results given which include descriptions of strength properties subsequent to heat-treatment, dependence of notched-bar impact strength, fatigue vibratory strength of polished test bars, examination of welded joints, and strength properties in the casting.—R.S.F.C.

Red loamy sand from Olsztyn (Poland) J. Szreniawski and H. Moneta (Politechnica Lodzka, Mechanica, 1960, 29, (7), 85–98) The properties of this sand as mined with 9 to 16% of bond have been compared with these of the same sand but de-loamed with the same bond added afterwards, and no essential difference has been found as far as porosity, resistance to crushing, and shearing were concerned. The porosity of the de-loamed sand was equal to

porosity of the de-loamed saind was equal to that of the finest fraction of the sand as mined. Mineralogy of moulding sand W. P. Winter (Foundry, 1960, 38, Nov., 103-105) The first of a series of six articles on sand topics covers US deposits, fundamental properties, grain geometry, and composition, and processing features. -S.H.-S.

Nuclear water witching upgrades foundry sand General Motors Corp. (Steel, 1961, 148, March 27, 164-165) A system, featuring a probe containing a radioactive material, which indicates moisture content and water addition necessary to maintain sand within specifications, is described .- s.H.-s.

Green tensile and shear strengths of moulding sands R. W. Heine, E. H. King, and J. S. Schumacher (Trans. AFS, 1959, 67, 229-236) Moisture content of a green sand largely controls the green shear and tensile strength, these values decreasing as moisture increases; moisture contents > 4.4% were too wet but if much below that which is required for coating the sand and clay, tensile and shear properties decrease and are erratic and the sand is too dry and brittle for moulding. The effect of ramming is considered and green tensile and green compressive strengths are proportional to green shear strength and this latter is related to mould hardness. Increased ramming causes the green tensile strength to reach a max. between 3-4 psi. These results have been obtained with, 8, 10, and 12% western bentonite. The same concentrations of southern bentonite have also been studied and similar results have been obtained. Mixtures containing 10 and 15% fireclay display the same effect as a mixture low in western bentonite; green tensile strength <2.5 psi and even at 15% fireclay the green tensile and shear strengths remain low; this is due to the fact that it takes ~25% fireclay to approach the clay saturation required for the higher values; a concentration of 25% is also used. The effect of sand fineness (AFS 49-85, silica and bank sands) is considered, but the results do not appear to be decisive. Green tensile, shear, and compressive strengths and mould hardness relationships were not affected by cellulose additives but carbonized cellulose permitted a higher tensile strength to be reached by ramming.-c.v.

New sand mix doubles core production (Mod. Castings, 1961, 39, March, 54-56) This mix, with an urea—CH<sub>2</sub>O resin binder, is cheaper than previous mixes, Methods of using it are

Systematic approach to sand design and control. 4 A. H. Zrimsek and G. J. Vingas (Mod. Castings, 1961, 39, March, 73-88) The effect of wood flour as a variable in the physical properties of clay-sand-water systems is considered. This report uses the previous work

(in reports 1 to 3) as a basis.

Contributions to the study of moulding mixtures with bentonites from Valea Chioarului E. Cohen, C. Bratescu, and L. Sofroni (Met. Constr. Masimi, 1960, 12, (12), 1059-1067) Moulding mixtures containing 3-5% bentonite from Valea Chioarului (comprising montite from Chioarului (comprisi morillonite, baidelite, and nontronite) and 95-97% sand were studied, and their characteristics and performance determined with various additives. If only bentonite is used, the optimal properties were attained when the  $H_2O$  is 0.7-0.8% of the weight of bentonite, at 6-8 min. mixing time. Increase of the latter improves the technological properties and correspondingly the  $H_2O$  percentage will increase. Petroleum coke gave good results as antiadherent additive, the  $H_2O$  percentage being 1–1·2% of the bentonite. Utilization of activators, of which NaOH is the most economical, improves the quality of the forming mixtures and increases the compression resist ance. Use of both NaOH and petroleum coke increases the compression resistance much more than either by itself.—M.L.

Methods for determination of moulding sand humidity H. J. Dietze (Giessereitech., 1961, 7, March, 68-71) The customary methods of determination of the humidity in moulding sands are reviewed in a series of three articles. In the first part the non-electrical humidity measuring methods are described, covering determination of humidity by drying, with the aid of CaC2 and by solvent extraction of the water, and evaluating their accuracies and

applications.

Relationship between the tendency of green moulding sands to cause casting defects, and their wet strength W. Patterson and D. Boenisch (Giesserei, 1961, 48, April 6, 157-166) A series of moulding sands with four normal bentonites of varied content in the natural state and after activation were studied for their green strength, wet strength, and the tendency to cause casting defects by scab formation. It was determined that increase of wet strength and reduction of pressure and wettability cause decrease in the scab-forming tendency. New testing methods for wet strength and scab specimens enable prevention of defect formation .- M.L.

Some little known materials used for moulding and melting (Fonderia, 1961, 10, March, 111-114) [In Italian] A brief description of the characteristics and applications of sillimanite, mullite, forsterite, olivine, glauconite, ethyl silicate, exothermic materials, zircon sand, and other materials and fluids.

Mould paints and washes for use in the steel foundry J. W. Middleton and P. G. McIlroy (IGK Kongress Vorträge, 27th International Foundry Congress, Zürich, 1960, 237–250) [In English] The influence of a number of variables on the room temp. properties of mould paints has been studied, and the results are reported

and discussed.

Machined patterns can be competitive R. Olson (Mod. Castings, 1961, 39, March, 89-94) The author describes ways to produce allmachined patterns nmore accurately, faster and less expensively than has been done in the past. The resultant patterns are more durable than many of those made in newer ways.

Standardization of flasks in Hungary B. Hollosi (Koh. Lapok-Öntöde, 1960, 11, Sept., 199-202) The standardization of flasks in Hungary is proposed and specifications are designed by the author.—P.K.

Feeding distance of bars in investment moulds H. Present and H. Rosenthal (Mod. Castings, 1961, 39, March, 70-72) The case of a round bar fed by an infinite riser was considered. Armco iron, AISI 1020, and AISI 1095 steels were used.

The use of models in studies of the flow of metals in gating systems M. Bednářík (Slévar-enství, 1961, 9, (1), 2-5) [In Czech] The utiliza-tion of similarity theory in the design and use of plastic models of gating systems in foundry reserach is discussed with special reference to the author's own work. The casting of blades of Kaplan turbines is given particular consideration.

Determination and calculation of the risers in the riser-gate casting process A. Holzmüller (Giesserei, 1960, 47, Sept. 8, 497-501) The method described as based on a paper by Patterson and Koppe (cf. Giesserei techn.-wiss Beih., 1960, (27), 1463–1476), and is illustrated by example

Design of metal flow as an aid to gating technology M. Bednářík (Giesserei, 1961, 48, Jan. 26, 25–33; IGK Kongress Vorträge, 27th International Foundry Congress, Zürich, 1960, 189-205) Possible applications of model studies and similarity theory to the design of optimum gating systems were investigated with successful results. Conditions for retaining impurities in the gating system, and flow patterns in the casting were studied (22 refs).

A general method for riser dimensioning W. Patterson and W. Koppe (Giesserei Techn.-Wiss. Beih., 1960, (30), Oct., 1647-1654) The general riser equation according to Namur is discussed, and the equivalence of other methods shown. The use of the general equation is then examined, and some simplifications dis-

cussed (11 refs)

Breakability of knock-off risers P. K. Sandell (Foundry, 1960, 88, Nov., 92-95) Proper practice and results of testing various shapes and sizes of knock-off riser cores are discussed. It is suggested that a knock-off core should be as thick as possible within the requirements of sound feeding, and tests indicate that a thickness of about 10% of the riser diameter plus 0.2in is safe.—s.H.-s.

The thermal efficiency of risers and the yield W. Patterson and W. Koppe (Giesserei Techn.-Wiss. Beih., 1960, (28), April, 1523-1533) Factors influencing riser efficiency are discussed, where 'efficiency' is defined as  $\beta V_0/V'$ < 100%, in which  $\beta =$  the shrinkage coefficients, Vo the cast volume to be fed, and V' the riser volume. Factors influencing yield are discussed, and an example given. The treatment is theoretical (12 refs).

Ramming, superheat and alloys (type of metal) effects on metal penetration G. J. Vingas (Trans. AFS, 1960, 67, 671-675) The major variables associated with this problem are the relationship of mass of sand to mass of metal, the pressure (determined by the height of liquid metal above the sand surface, into which the metal is penetrating), and void size of the sand mass; the minor variables are superheat, metal flow, washes and coatings, glazing (sintering), gas pressure (very minor), and veining. With Al, ramming affects penetration but superheat does not, with brass ramming does not affect penetration but superheat is a most important variable and with iron, both ramming and superheat have an effect.-

Internal defects in steel castings . nature and how they can be avoided J. M. Mowat and P. Packham (Found. Trade J., 1961, 110, Mar. 23, 369-370) A brief review from a W. Scotland ISI symposium.—c.v.

The qualitative influence of the size factor on internal stresses in castings J. Přibyl (Sborník, (Ostrava), 1960, **6**, (3-4), 303-313) [In Czech] Basic questions of the design of large rigid castings are considered from the point of view of minimizing cooling stresses .- P. F.

Microclimates and dust problems in foundries I. Berka (Slévárenství, 1961, 9, (2), 46-48) [In Czech] The origin and control of temp. and humidity variations, as well as problems of reduction of air pollution by dust, are discussed on the basis of researches carried out in a large modern grey-iron foundry. The utilization of the results in the design of new foundries is considered .- P.F.

### VACUUM METALLURGY

Ball bearing steel made with a vacuum induction furnace M. Ueno and H. Nakajima (Rep. Nat. Res. Inst. Metals, 1960, 2, March, 213–218; from Japan Sci. Rev. Mech. Elect. Eng., 1960, 7, Aug., 272)[No abstract].—c.f.c.

Degassing of steel in vacuum for use in aircraft castings J. K. Dietz (AIMME, Proc. Elec. Furn. Conf. 1959, 17, 223-225) The author outlines the design of a simple vacuum melting and degassing unit for foundry use, and quotes typical results.—G.F.

Investigation of degassing processes in treat-

ment of steel drops under vacuum L. (Jernkont. Ann., 1960, 144, (10), 757-770) [In English] The mechanism of the boiling observed on lowering the pressure to 400 mm Hg below the equilibrium pressure of CO in the steel is discussed.—(14 refs.)

Equipment used in vacuum degassing in the foundry W. F. Hipple (AIMME, Proc. Elec. Furn. Conf., 1959, 17, 231–239) The author describes vacuum degassing units which can now be profitably used in the steel foundry. Particular attention is given to the 'bell-jar' unit used at Pacific Alloy Corporation for producing aircraft castings. -G.F.

Vacuum treatment of open-hearth alloy steel K. M. Petrov and V. A. D'yakonov (Stal', 1961, (4), 383) A note from UIChM. Successful vacuum treatment processes at several plants

are briefly referred to.

Vacuum induction melting: oxygen and carbon in iron J. E. Srawley (PB 161764. Final rept. on phase I. 1960, Sept., pp.20; NRL rept. 5516; from US Res. Rept., 1961, 35, Jan. 13, 92) Initial O<sub>2</sub> contents of 200-300 pmm were reduced to ~20 ppm by adding C. Excess reacted with the crucible, Al<sub>2</sub>O<sub>3</sub> being less reactive than ZrO<sub>2</sub> or MgO. The usefulness of leak-up rates for process control is noted.

Vacuum melting produces better brazing

Vacuum melting produces better brazing alloys C. R. Benson (Weld J., 1961, 40, March, 232–236) The characteristics, benefits, and applications of vacuum brazing alloys are

described and discussed .- s. H .- s

Vacuum casting in the Polish steel-making industry M. Stankiewicz and J. Obrebski (Hutnik, 1961, 28, (2), 37-44) At the beginning of 1959 there had been installed 4 vacuum pumps and 2 vacuum chambers at the Batory steelworks to cast 2.5 to 6 t ingots. The pumps (a modified Polish design of Kinney's eccentric pump) have a capacity of 900 m<sup>3</sup>/h driven by 26 kW motor, using 3 m<sup>3</sup>/h of cooling water and 0.251 per h of oil (moisture: nil, viscosity 6-7° Engler at 50°C, acidity: max 0.05, flash point: 200-240°C). All refractory used in vacuum casting should be of highest quality with a high content of alumina. The amount of  $\rm H_2$  dropped from 6.45 ec  $\rm H_2/100~g$  to 3.58 ec  $\rm H_2/100~g$ .

High vacuum annealing: Its use in steel wire drawing and cold rolling mills W. Herdiecker-hoff (Wire Wire Prod., 1961, 36, 470-471, 473, 518-519) A brief, but quite detailed summary

of the process .- c. v.

Vacuum and controlled atmosphere heattreatments specialized at Metallurgical Consultants, Inc (Indust. Heat., 1960, 27, Nov., 2503-2512) Details are given of a versatile installation for all types of heat-treating and brazing, and for specific unusual applications tiny electronic and magnetic components and brazing of stainless steel .- K.E.J.

# REHEATING FURNACES AND SOAKING PITS

A comparison of regenerative and recuperative soaking pits S. H. Brooks (Second Recuperator Conference, (Schack system), Paris, 24–25 Apr., 1959, 9–24, II 1–8, Appendix 3–4) A comparison is made between the newer decision of pits regenerative (res. recuperative) designs of air regenerative/gas recuperative pits and the fully recuperative units, with reference to practice at Appleby-Frodingham. Details of performance are given, and economic factors are examined. It is considered on balance that the recuperator design offers the most promise. Development of steel recupera-tors for soaking pits of August-Thyssen-Hütte in Duisberg-Hamborn K. Schmitz (3-7, I 1-2, Appendix 1-2) The development of the steel recuperators for the one-way fired soaking pits installed at the A.T.H. works is described, with design details and an account of experience with the system. Radiation recuperators on oil fired soaking pits J. F. Whitfield (25-29, III 1-6, Appendix 5-6) Details of the installation at the Round Oak Steel Works of T.I. and its performance are given.

The working of regenerator soaking pits of a blooming mill with the removal of the liquid slag I. I. Sterlikov (Metallurg, 1960, (12), 26–29) At the MMK the shortcomings of the existing regenerator soaking pits have been removed by mounting reversing valves system

'Forter' and 'Simplex' in each compartment formerly fitted with a flue-gas slide valve. In this way each compartment was rendered independent of the unit and the capacity was increased by about 25%.

Design of new continuous reheating furnaces of thin sheet mills S. M. Nosenko (Stal', 1961, (4), 367-371) The Stal'prockt design is described and discussed. Experience at various works and with various items is called upon in the design and data still required are indicated.

Preheat furnace increases freight car wheel production of rotary hearth heat-freating furnace Griffin Wheel Co. (Indust. Heat, 1960, 27, Dec., 2548-2552) The preheat furnace has increased production by 25%. Previously the wheels in 1070 carbon steel, needed 62 min in the rotary furnace. The preheat furnace heats 30 wheels per h from  $1\,000^\circ$  to  $1\,500^\circ$ F. It has two zones; is of the direct, over-fired design; and burns natural gas and propane.-K.E.J.

# HEAT-TREATMENT AND HEAT-TREATMENT FURNACES

Controlled atmospheres for heat-treatment L. G. W. Palethorpe (Overseas Eng., 1961, 34, Mar., 238-240) It is stressed that most of the atmospheres considered contain  $H_2$  or CO, that either of these mixed with air can be very explosive, and that satisfactory controls are imperative for this reason as well as for effective treatment. The necessity for correct furnace design is also emphasized.—c.v.

Unique heat-treating installation processes 40,000 different parts H. L. Hopkins (Indust. Heat., 1960, 27, Oct., 2054–2062, 2066) The parts include bolts, nuts, screws, rivets, cetter pins and tacks. Full details are given of the installation, based on two continuous-belt hardening furnaces and a battery of ten air-

draw tempering furnaces. -K.E.J

Heat-treating the stainless steels. VI. Heat treatments for precipitation hardening stainless steels S. W. Cole (Indust. Heat, 1960, 27, Oct., 2037, 2038, 2040, 2042, 2044, 2046, 2048, 2050, 2052) Full details are given of the chemical composition and heat-treatments required for various conditions, for 17-7 PH, 17-4 PH and PH 15-7 Mo steels.—K.E

Type 330 alloy trays withstand thermal shock in continuous heat-treatment of steering gear parts Ford Motor Co. (Indust. Heat, 1960, 27, Dec., 2572–2576) The trays are used for holding parts vertically in a carburizing cycle. The thermal shock of oil quenching had damaged the previous trays. The present ones are made from 14in × 3in bars. (on edge).

Carburization of austenitic stainless steel in liquid sodium W. J. Anderson and G. V. Sneesby (NAA-SR-5282, 1960, Sept., pp.27; from US Res. Rept., 1961, **35**, Jan. 13, 128)

[No abstract].

Control of high temperature carburizing.
(High temperature carburizing II) W. H. Holoroft (Indust. Heat, 1960, 27, Oct., 2073–2082, 2230–2234, 2254) A high carburizing potential is needed in the first stage of the cycle, followed by gradual decrease of potential. Control can be effected by an infra-red analyser working on  $\operatorname{CH}_4$  and  $\operatorname{CO}_2$ . The chromatography type of instrument is under development.—K.E.J.

It's submerged hardening for these gears D. Fishlock (Metalw. Prod., 1961, 105, Apr. 5, 47-49) A description is given of the Cold-Heat method of induction hardening used by Stothert and Pitt Ltd, Bath; this is based on 2 years experience, 850-900 gears being produced monthly. They are precision cut and enter service with no further treatment after hardening. The materials used are En.8D 40-C-steel (good wear properties) and En.24T 1.5% Ni-Cr-Mo which is employed where maximum core strength is required. The process is described.

Gaseous decarburization of white cast irons J. Burke, J. Bell, and D. R. Bourne (*Acta Met.*, 1960, **8**, Dec., 864–870) Decarburization of two white cast irons, differing only in microstructure, has been studied, using a 20 % CO<sub>2</sub>-80 % CO atmosphere. Carbon loss and depth of decarburization at 1000°C and 1050°C were measured as a function of time. A mathematical analysis of decarburization is developed and from a comparison of this with the

experimental results it is concluded that the diffusion of carbon in austenite is the rate

controlling process.

controlling process.—S.H.-S.

Fast heating accomplishes uniform spheroidizing of heading stock J. Tschopp (Wire Wire Prod., 1961, 36, Apr., 463, 515) The Chicago Screw Company has installed a 102 ft continuous pusher type furnace for spheroidizing steel coil stock used for cold headed products. The trays are advanced through the furnace and discharged automatically by a hydraulic mechanism. The furnace has six temp. zones and the operation is briefly described, and photomicrographs show the structure of 1035 and 4140 steels as-received and after spheroi-

Stress-relieving large weldments by radiant heating T. Bishop (Met. Prog., 1961, 79, Jan., 124) The practice of manufacturing halves of turbine casings by welded construction (21 ft 17 ft × 18 ft) and then relieving stress by radiant electric heating is discussed. Due to the amount of metal and the complicated nature of the structure 68 single-phase radiant heating elements each of 7½ kw were used; the heaters were arranged so as to ensure even heating and all were individually controlled. When the temp. attained 1200°F, the power. input was reduced to keep the temp. constant for 3 h while the casing soaked. Heaters were then turned off and it was allowed to cool to ambient temp. The arrangement is suited for automatic control .- C. V

Continuous annealing line drive systems R. M. Bosshardt (Iron Steel Eng., 1960, 37, Dec., 125-131) Drive features of the three continuous annealing lines being installed for US Steel Corp. at the Gary Sheet and Tin Mill, Gary, Ind., Columbia-Geneva Div., Pittsburgh, Cal., and Tennessee Coal and Iron Div., Fairfield, Ala. are described and discussed.

Allegheny Ludium starts two continuous bright annealing lines (Iron Steel Eng., 1960, 37, Dec., 191) A note on the bright annealed stainless steel strip being produced at two Allegheny Ludium plants.

Annealing steels for roller bearings J. Bursa (Hutnik, 1961, 11, (2), 55–58) [In Czech] On, the basis of metallographic studies alterations in the annealing schedules were introduced in the Bílá Cerkev Steelworks in Czechoslovakia. These are discussed.—P.F.

Open coil processes of annealing and gas alloying Lee Wilson Engineering Co. (Engineer, 1960, **210,** Oct. 14, 650-651) This system provides for a separation, or air space, between the individual wraps of cold rolled steel coils, the annealing atmosphere gas being passed through these spaces so that the entire coil can be very rapidly heated and cooled. Apart from annealing, this method can be employed to change the composition of the steel, C, N and other alloying elements that can be gasified being added or removed.—c.v

Cable stranding and induction stress relieving S. V. Stickler, jun and G. F. Bobart (Blast Furnace Steel Plant, 1960, **48**, Dec., 1251–1254) The first installation of induction heating equipment for stress relieving steel cable as it is produced on a stranding machine is des-cribed. The equipment was installed in an American plant

Automatic austempering unit speeds electric typewriter parts production Business Machines orp. (Indust. Heat, 1960, 27, Nov., 2334-2346) Uniform structure and properties are produced in type bars in a fully automatic cycle, which comprises heating to 1550°F in 25 sec in a Duradiant-fired furnace, salt-bath quenching at 680°F for 15 min, washing and drying.

# FORGING, STAMPING, DRAWING AND PRESSING

Programme control for forging press and manipulator T. Bishop (*Met. Prog.*, 1961, **79**, Jan., 94–96) The work of BISRA in this direction is reported. It is shown that manual control of a press usually results in more strokes than is necessary; also it was found that a 2000 t press was idle for 20% of its time as the crane used for loading was otherwise occupied. The design of the manipulator necessitated longitudinal motion back and forth and accurate rotation through 90, 45, 22.5 and 9.5°. The trials with the pilot plant are continuing but the surface finishing and accuracy of the work promises well.-c.v

The forging of hot steel and the use of moulds I he torging or not steel and the use of moulds J. M. França (Geol. e Met., 1960, 15, No. 22, Dec., 11-69) [In Portuguese] A handbook in four sections comprising: (I) Fundamentals of metals and alloys; (II) Factors influencing the shaping of metals; (III) Forging equipment; (IV) Technology of mould manufacture; with an appendix of forging tolerances as laid down by the American Drop. Foreign Association.

by the American Drop Forging Association.

Forming and heat-treating at International
Harvester's Fort Wayne Works A. Q. Smith
(Indust. Heat, 1960, 27, Dec., 2560–2564) The
plant making heavy-duty trucks has 24 forge furnaces fired with combination gas and oil burners, 48 gas-fired batch and continuous heat-treatment furnaces, 7 prepared-atm. generators and a special furnace for flame-

drawing of axle shafts.—K.E.J.
Ingot and forging defects arising in the
process of solidification and crystallization V.
Košelev and S. Burda (Hutnik, 1961, 11, (3), 110-117) [In Czech] Defects, such as are due to volume changes on solidification, and to dendrite formation, are discussed on the basis of the extensive experience of the authors in

the Lenin Works in Pilsen.—P.F.

Metal properties involved in the bending of sheet metal Z. Marciniak (Obróbka Plastyczna, 1959, 1, (2), 93-102) Various formulae are derived which take the many factors into consideration. The methods used to determine the work-hardening characteristics of the bent metal are described and the results obtained with various materials are given .- C. V.

Formability tests for sheet metal T. Bishop (Met. Prog., 1960, 78, Nov., 95-98) The available tests are discussed, and their limitations as shop floor tests indicated.

Forming galvanized sheet steel P. G. Nelson (Met. Prog., 1960, 78, Nov., 93-95) Properties of galvanized sheet are summarized, including differentially coated sheet. Preliminary experience indicates that galvanized sheet can be formed as readily as uncoated sheet, but not with the same tooling.

Description of a metalworking machine constructed by the Press and Hammer Design Gentral Office J. Romanowski (Obróbka Plastyczna, 1959, 1, No. 1, 95–112) Illustrations and drawings are given.-c.v.

Deformation of a drawn heavy-gauge sheet metal and the shape of the draw die V. Vrzal (Obróbka Plastyczna, 1959, 1, No. 2, 123–138) Tests carried out on heavy-gauge sheet metal, deep drawn without blank holding, are described. Variously shaped dies and punches with varving radii have been used. Causes of failure are analysed on the basis of strains exerted on the internal and external surfaces. Based upon performance it would appear that optimum results are attained with dies with a tapered hole and small draw-edge radii.—c.v.

Factors affecting the drawability of sheet steel R. L. Whiteley (Blast Furn. Steel Plant, 1960, 48, Dec., 1245-1250) Principles underlying the deep drawing process are outlined, the limits of a successful deep drawing operation are illustrated graphically, tool design and mate-rial factors affecting drawability are discussed, and the anisotropy of sheet metal and its relation to drawability are indicated. (12 refs).

A study on reverse redrawing of round and squared shells F. Tychowski (Obrobka Plastyczna, 1959, 1, No.1, 11-54) The work of S. J. Chung (assuming the Tresca condition of plasticity) and the earlier work of the present author and Z. Wisniewski are discussed; in this latter work the Huber-Neneck-Mises condition of plasticity was assumed and is the basis of this study. Formulae and nomographs are given which enable the stresses and redrawing forces to be determined for an arbitrary coefficient of friction with or without the blankholder .- c. v.

High energy forming: Use of hydrodynamic properties to shape metals with Dynapak machine test S. R. Carpenter (Air. Eng., 1960, 32, Feb., 53-54) Machine tools have been developed to produce high energy levels at high rates and it is shown that metals possess hydrodynamic properties when subjected to these conditions which facilitate shaping. This

is applied to steel and various other metals so that thin sections can be extruded and forged. A sectional view of the Dynapak high energy rate machine is given and typical shapes produced are shown. The following points are specially noted: unsymmetrical sections, sharp definition of section and die filling, high ratio of thick to thin section (ratios of 20, with min thinness 0.035in have been attained), abrupt changes of section, hollow sections with internal and external fins and min corner radii. The economic advantages are discussed .- c. v

Explosives in metalworking H. Thomas and S. Paterson (Metalw. Prod., 1961, 105, Feb. 22, 47-50) The combination of explosives technology with conventional methods in sheet metal forming operations is described, with quantitative data on the explosives used and their behaviour. The charge is immersed in water and located at a predetermined dist-ance above the sheet metal blank. On firing the charge the shock waves generated force the blank to take up the shape of the die.—s. H.-s.

The process of explosive forming of metals W. S. Hollis (Product. Eng., 1961, 40, March, 216–225) Explosive forming is defined and the principles are outlined, the work at present being carried out in the UK being surveyed. Costs and development are summarized and it would appear that unless attractive metallurgical gains can be realized, future developments will concern those components outside the capacity of available presses or those which are so complex as to demand high capital expenditure in acquiring hydroforming equipment. The advantages however lie in dispenswith inter-stage annealing, simplifying weldment constructions, improving weld area and ductility and raising the ultimate yield strength of the metal. These advantages are perhaps specially applicable to new difficultto-form materials.—c.v.

The principles and practice of explosive metal forming L. Zernow (Sheet Metal Ind., 1960, 37, Dec., 897-900, 904) The author deals with the various parameters of explosive forming such as energy source, energy transfer medium, strain rate, materials formed, and economical aspects. He also gives examples of typical products such as pressure-vessel closures.—A.H.M.

Safety with explosive forming H. Thomas (Metalw. Prod., 1961, 105, Feb. 22, 51-52) While explosives, of their very nature, present a hazard, the safety record in the manufacture and use of industrial explosives is very high and with care and attention explosives and their accessories may be handled in routine operations. The legal and safety aspects associated with explosive storage and handling as concerning personnel in sheet metal forming by explosion techniques are discussed with the intention of service as a useful guide in drawing up a code of operational regulations for their specific problems .- s. H.-S.

Hardening points and crossings by explosives (Rail Gaz., 1961, 114, Jan. 20, 80) Sheet-fo explosive developed by DuPont, which 80) Sheet-form basically pentaerithritol tetranitrate (PETN), and its application to the hardening of the regions of greatest rail track wear (e.g. points and crossings) with the advantage of pliability enabling it to be cut and fitted to surfaces of any shape, is briefly described, and the method

of application illustrated .- s. H.-s.

Explosive attack in mild steel M. Ishii, S. Murai, and K. Umeya (Met. Phys., 1960, 6, Nov., 264-266) [In Japanese] [No summary].

Rohr puts electroforming on line G. C. Cadwell (Steel, 1961, 148, March 27, 168–168) A process, delivering an impact of electrical energy which moves as a shock wave to force a part into a die, is briefly described.—s. H.-S.

Action of a fluxing addition in the mould during the pouring of rimmed deep drawing steel and its influence on the quality of the sheet Teindl and B. Otta (Neue Hütte, 1961, 6, Jan., 17-22) An addition of 'Olsit' (70% seale, 20% fluorspar, and 10% soda) was added during pouring to a test ingot of deep-drawing quality rimmed steel, a normal ingot being poured at the same time for comparison purpose that the same time for comparison purpose the same time for compariso poses. Both ingots were rolled into sheet. The treated ingot rose less in the mould, and the deep-drawing value of the sheet was 2.75%

higher, with 2.5% less scrap on deep drawing, It appeared to have a somewhat greater susceptibility to ageing. Trials on a large series of melts confirmed an improved yield on rolling and reduced scrap on drawing (1.04%)

Distortion-free drawn products by re-drawing H. Bühler and A. Peiter (Draht, 1960, 11, Aug., 398-405) The mechanism of the process described in detail, and illustrated by examples

Development of deep drawing ageing-resistant steel for heavy duty pressings J. Sole, M. Zezulova, and Z. Zdeněk (*Hutn. Listy*, 1961, **16**, March, 159–168) The properties of this steel are discussed, with the advisability of using the oxygen converter for its production. Results of practical tests are given.

The hot drawing of steel with glass lubricant L. Labataille (Rev. Techn. Luxembourg, 1960, 52, Oct.—Dec., 203—210) [In French] The development of glass lubrication and the technique of its application to hot drawing are described, and the properties of the drawn metal are discussed. Economics, applications, and the present state of development of the process are reviewed.

Fundamental knowledge relating to processes for deep drawing and pressing H. T. Coupland (Sheet Metal Ind., 1960, Nov., 831-836, 846) The author describes the precise meaning of deep drawing and considers the mechanism of the process, the effect of friction and lubrication and the effects of drawing

A stretch-forming test for use with a variablespeed drawing press D. V. Wilson, B. B. Moreton, and R. D. Butler (Sheet Metal Ind., 1961 38, Jan., 25-36, 42) A new stretch-forming test which can be carried out on a Swift drawing press is described. This uses a standard 2-in dia. punch and allows a choice of penetration speeds up to 100 ft/min. Experimental results are presented which illustrate some of the advantages of the test. A method of rapid testing which eliminates the necessity for stopping the test just before fracture is finally described.

Observations upon production planning and control in a steel wire mill D. W. Bedford (Wire World Int., 1961, 3, Feb., 24–28) A very detailed summary dealing with administration aimed at assisting the various sections of the company to be efficient units. A plea is made for the introduction of fewer items of plant and machinery, each being capable of increased output; this makes efficient planning and prossing more imperative so that idle time of highly paid men and valuable machinery is cut to a minimum. -- C. V

Development in the design of wire coilers used in iron and steelworks in Germany and elsewhere P. Grüner (Draht, 1960, 11, Aug., 422-425) Various systems are described and illustrated.

Pre-treatment of rolled wire for drawing through a phosphate and waterglass coating I. M. Goncharov, L. I. Fudim, F. M. Ladyzhenskaya, and O. A. Ryabehikova (Wire World Int., 1961, 3, Feb., 29-30; from Stal', 1957, (5), 464-465) The findings of this experimental work show that the life of the drawing dies is extended by ~15%. drawing output is increased by 15-20% due to the fact that breaking or wedging do not occur, Cu-plating can be dispensed with and working conditions are improved. However, wire so treated cannot be wet-drawn and it is difficult to hot galvan-

Do molybdenum disulphide-containing wire drawing lubricants have a place in your mill? W. A. Smigel and W. M. Stillwell (Wire Wire Prod., 1961, 36, March, 313-314, 376) The early use is summarized and the use in the production of wire, rope, welding rod, Al-core, and nail wire, spring, high-C, and chain link fence wires is indicated. It is not a 'cure-all' and formulation must be correct; currently 10-15% of all wire-drawing lubricants contain MoS<sub>2</sub>. It is stated that the quality is improved and cost is reduced since drawing speed is increased, rejects are reduced and a better die

Estimating strains in the walls of deep drawn parts Z. Rusinek (Obróbka Plastyczna, 1959, 1, No. 2, 139-147) Simple formulae are proposed to allow the strains along the generating line in the wall of deep drawn parts to be

calculated.-c.v

Elongation vs. reduction, a new precept A. F.Mahrnheim (Wire, 1961, Feb., 21-24) By using the elongation factor instead of % reduction in area as a principal measure of plastic deformation, simple relationships are revealed and wire and tube drawing calculations can be greatly simplified. Several examples are given.

A scientific basis of the transfer and progressive drawing processes I. A. Noricyn (Obróbka Plastyczna, 1959, 1, (2), 41–73) A theoretical basis of transfer and/or progressive (multistage) drawing and annealing is proposed, which is based on a generalized scheme of strains; this is valid for every draw including cupping. A generalized equation is given for the drawing process; the formulae permit of the computation of maximum flow stress, maximum drawing forces in the first cupping draw and for the subsequent operations and the inverse drawing ratios for cupping and the subsequent draws can also be derived. A general deformation scheme is given which includes the push-sinking of the preformed shell through the die with the assistance of a rigid blank holder or stepped punch and it is claimed that exceptionally high drawing ratios can be attained without interstage annealing. The work has been carried out with Al and brass sheets .- c. v.

Exchangeable cemented carbide dies for sheet metal drawing, L. Rybczynski (Obróbka Plastyczna, 1959, 1, (2), 103–122) The behaviour of WC dies in the production of thick walled shells is studied. A method of calculating shrinkage is discussed; this is based on Lamé's principle and the autofrettage theory.-

The fundamentals of wire drawing. X. The parallel in the die C. P. Bernhoeft (Wire Ind., 1961, 28, Apr., 388-390) For all wires 0.5in, and under, the length or height of the parallel should be a max. 75% of the wire diam. when the die is new. With larger diam. wires, this figure can be reduced to 50% but the die angle ways he increased Several or approach of this premust be increased. Several examples of this are given and these are discussed. Lubricants are onsidered and the requirements are listed. The advance in hydrodynamic lubrication is mentioned and it is suggested that this may result in great saving in drawing power, increase in die life and reduction in cost.—c.v.

Machinery for forming mass-production parts from wire (Wire, 1961, Feb., 1-7) Several units for cold forging or cold extrusion are described and illustrated.

New ways in cold extrusion of steel F. Hrazdil (Obróbka Plastyczna, 1959, 1, (2), 149–162) Work carried out in the Metal Working Institute, Břno, is described. The behaviour and properties of the compressed region of a steel blank subjected to cold, impact, backward or radial extrusion is considered and some cases of forward cold extrusion are also considered. Formulae are discussed for the calculation of forward and backward extrusion forces.-- c. v.

A study of cracks in extruded metal T. Pelczynski (Obróbka Plastyczna, 1959, 1, (2), 23-40) The state of stress generated during metal extrusion is considered; this occurs inside the container and the die and in the areas directly adjacent to the die. Coherence in the extruded material is found when Z > rwhere Z is the working capacity of the given forming process and r is the resistance of the material to reach the plastic state. The value of r will thus determine the tendency of the material to brittle fracture. The temp. and extrusion speed will alter the r values and that of Z can be changed by modification of the shape of the die.-c.v.

### ROLLING MILL PRACTICE

Successful rolling of ingots of Kh25T steel M. N. Kul'kova, P. N. Sporyshkov, and V. V. Turitsyn (Stal', 1961, (4), 354–355) Some heats gave slabs with a tendency to fracture even during transportation or cutting. Three heats were examined and suitable heat-treatments were found. Heating above 1100° greatly reduces ductility by promoting separation of coarse ferrite.

Flat rolled products made from oxygen converter steel T. Ikeda (J. Australian Inst. Met., 1960, 5, Nov., 209-220) The rapid growth of

production of oxygen converter steel in Japan is discussed, and details at given of the pro-cess as practised at Tobata Works of Yawata Iron & Steel Co. Ltd. The characteristic properties of a number of flat-rolled products of this type of steel are given and compared with

Unitized automobiles C. W. Cenzer ('Flat rolled product II. Semi-finished and finished,' Interscience Publishers, 1960, 6, 83-97) The difference between the platform type con-struction and the single unit type is discussed and the advantages are pointed out. This form of body construction is also called single-unit, unibody and unistrut. Apart from initial design, many other problems are briefly reviewed: suspension, sound-deadening materials, instru-

ment panel, heating systems, etc.—C.v.

Committee for large and small rolling mills:
Study of maintenance in finishing operations
De Lafon (Centre Doc. Sider. Circ., 1960, 17,
(6), 1493) A study of improvements in productivity finishing operations in various small mills which could be achieved by better or-

mills which could be achieved by better organization planning and use of equipment.

Temper rolling and its effect on stretcher strain sensitivity E. J. Paliwoda and I. I. Bessen ('Flat rolled products. II. Semi-finished and finished', Interscience Publishers, 1960, 6, 63-81) It is shown that temper-rolling is a bettergreeous process leaving the surface heterogeneous process leaving the surface layers work hardened and the interior discontinuously deformed. This heterogeneity masks the yield elongation and it would appear that a series of macro-stresses must have been produced in samples just temper rolled. Those that have been temper rolled, coiled and lightly roller levelled provide data that suggests the formation of microstresses, these being responsible for yield elongation suppression. After ageing, discontinuous slip starts within unyielded regions but the work-hardened grains at the sheet surface appear to act as obstacles. Various other extensions of this argument are presented.—c.v.

Graphical determination of rolling force in cold rolling H. Hennig and M. Wenzel (Arch Eisenh., 1960, 31, Dec., 703–707) Nomograms are developed and their use explained for the calculation of rolling forces with and without allowance for roll flattening and strip tensions, in the cold rolling of strip.

in the cold rolling of strip.

The wear of cast iron rolls and the nature of surface erosion V. S. Berkovskii, M. I. Lobarev, V. T. Khudik, and I. Yu. Chizhikova (Stal', 1961, (4), 340-343) A study of the hardness and structure of roll surfaces and of chips removed during regrinding is reported. Recom-mendations are made including one for changes in the present specification for cast iron rolls.

Effect of roll wear on spalling J. D. Keller (Iron Steel Eng., 1960, 37, Dec., 171-178) In connection with work being carried out by the Joint Roll Research Committee (AISE Roll Manufacturers' Institute) on the causes of roll spalling, amount of roll wear and its distribution along the length of work and backup rolls was investigated. The application of the roll contours or wear patterns to the determination of the distribution of load along the roll length and the stresses thereby produced is described.

Time study in a blooming mill K. Golebiowski (*Hutnik*, 1961, **28**, (2), 67–71) Out of 16680 sec of time measured, 4400 were idle, the bottleneck being 1000 t bloom shears working only at 51·8% capacity.

Analysis of the rolling process occurring in a 30 inch diamater grooved roll billet reducing mill S. Bala and J. Jońca (Hutnik, 1961, 11, (3), 117-123) [In Czech] Roll torque and roll pressure measurements made by the authors were utilized in rationalizing rolling procedure, e.g. the reduction of the number of passes required to roll 3½ t ingots of steel St 38 into close tolerance hexagonal shapes .-

The operation of a three-stand high speed rod and merchant mill A. H. Griffiths (Iron Steel Eng., 1960, 37, Nov., 139-143) The mill described is the new No. 2 rod mill at the Sheffield Div., Armco Steel Corp, Kansas City.

The efficiency of plate rolling mill universal stands: (discussion) G. M. Katsnel'son (Stal', 1961, (3), 246-249) Addition of equipment to produce tension and the centring of rolled stock would improve thickness uniformity and

edge form and reduce loss in edge trimming. The plates would also be reduced in weight with a total saving of 10-12%.

Steel rolling mill electrical drives: installasteel rolling mill electrical drives: Installations for cold reduction of strip and hot rolling of structural sections (Elect. Times, 1961, 139, Mar. 23, 493-494) A brief summary of two papers is presented: the first (H. D. Morgan and P. E. Peck) dealing with the development and control of high-speed cold reduction mills, with particular reference, to the four-stead with particular reference to the four-stand tandem mill belonging to the Abbey Works of the Steel Company of Wales; the second (A. P. Clark and R. E. Kenderdine) describing both mechanical and electrical features of universal beam and heavy structural mill at the Lackenby Works of Dorman Long Ltd. The electrical equipment of each plant is described .- s. H. - s

Rotary straightening of bars J. F. Wallace and D. H. Thompson (JISI, 1961, 199, Oct., 149-153) [This issue].

Hot machine scarfing of semi-finished carbon steels L. J. Trilli ('Flat Rolled Products. II. Semi-finished and finished', Interscience Publishers, 1960, 6, 3-21) Semi-automatic hot scarfing machines are usually placed in the roll table line behind the mill and ahead of the shears and as the slab or bloom travels towards these it passes through a burning zone where a layer of steel is oxidized or burned simultaneously from all faces over the entire length. Speed of travel, gas pressure and size of opening in the scarfing zone can be quickly adjusted. The scarfing heads are described and malfunctioning of these are discussed. Production results are examined and it is shown that this process may be used as the sole means of conditioning for a high percentage of steel. Several operational points are raised in the

Filtration in the iron and steel industry  $J.\ R.$ McCoy (Iron Steel Eng., 1960, 37, Dec., 148-154) Types of filters and their application to the filtering of rolling mill lubricants, and hydraulic and insulating oils are reviewed.

X-Ray inspection of hot steel billets during rolling W. J. Oosterkamp, J. Proper, and M. C. Teves (Metallurgia, 1960, 62, Dec., 257–260) A description of trial equipment installed by Phoenix-Rheinrohr for testing hot billets during rolling for cavities and inclusions, using 31 MeV X-rays and an industrial television 31 MeV X-rays and an industrial television system, and an X-ray image intensifier. A statistical analysis of results indicated that 50% of all cavities 3 mm thick and 90% of all cavities 7 mm thick were disclosed.

Giant ram trucks in Ebbw Vale steelworks K. Mumby (Mech. Handling, 1961, 48, Mar., 143-144) A Yale & Towne 'Giant Handler' ram truck, used to pick up huge coils of steel strip produced by a high-speed continuous process, with loads up to 20 t, is illustrated and its equipment and operation described .- s. H.-s.

Industrial after-sale relations between suppliers and users of rolled sheet L. Ya. Kats (Stal' 1961, (4), 363-364) Suggestions for better consultation to use the most suitable of a relatively few standard lengths and thicknesses

### MACHINERY AND SERVICES FOR IRON AND STEEL PLANT

Research in bulk materials handling M. J. Erisman (*Mech. Eng.*, 1961, **83**, Mar., 55–59) The Link Belt laboratory at Chicago, designed for the study of various froms of transport of materials, is described, with data on conveyability of materials and improvements in bucket elevators, centrifugal-discharge action, and increased capacity of belt conveyors.

Proposed bearing sections for AISE EOT crane specifications R. M. McCready and I. E. Madsen (Iron Steel Eng., 1960, 37, Nov., 97-101) The tentative revision of AISE Standard No. 6 for electric overhead travelling cranes is

Report on proposed A-C crane sections for AISE EOT crane specifications F. M. Blum and I. E. Madsen (Iron Steel Eng., 1960, 37, Nov., 101-106) A report on requirements for ac cranes being included in a draft specification for AISE Standard No. 6 for electric overhead travelling cranes.

Motor applications for heavy duty A-C crane service H. O. Poland (Iron Steel Eng., 1960, 37, Nov., 107-109) Factors to be taken into account in the design and construction of these ac motors are considered.

ac motors are considered.

Selection of A-C hoist motors on continuous duty cranes A. Nitsch (Iron Steel Eng., 1960, 37, Nov., 110-113) Applications, and torque and thermal requirements are considered.

Water economy in iron and steelmaking operations F. Wesemann (Föredrag vid Jernkontorets Tekniska Diskussionsmöte, 1958, May 31, pp.17) [In German] Circulating systems, hot cooling, and water treatment in the iron and steel industry are considered from the economic aspect. (15 refs).

### WELDING AND FLAME CUTTING

European welding research G. E. Claussen (Weld J., 1961, 40, March, 105-S and 129-S) Research articles in French, East German, and West German welding journals are briefly reviewed and translations from Spanish and

Russian papers are mentioned.—s.H.-s.

Status of welding processes in Europe M.
Komers (Met. Prog., 1961, 79, Jan., 107-112)
A general review of the most striking developments. Welding under powder, electroslag, Fusarc and shielded arc processes are specially

Transductor welding equipment K. Kless and E. Renz (AEG Prog., 1960, (1), 106-112) The use of transductors for control and as power

use of transductors for control and as power amplifiers for welding is described.—c.v. Fumes, gases and powders which affect health in welding J. D. Gallego (Cien. Tecn. Solda., 1960, 10, Jan/Feb., 0/052, 1-7) A discussion of the toxic effects of gases and powdered solids encountered in welding. (22

Mechanised welding line for open-web steel joists [United Welders, Inc.] (Mach. Shop Mag., 1960, 21, Dec., 734-738) The design of open-web steel joists has been standardized in 25 sizes with specific dimensions for depth, width, web-pitch and bearing plates related to custom-fitted span. United Welders, Inc., Bay City, Mich., has reduced fabrication time from several h to min and various machines in the line are duplicated so that two of the 25 standard joist sizes can be fabricated simultaneously. The layout and various units are illustrated .-- c. v

Technique for spot welding low carbon steel from 0.022 in (24 SWG) to in (Rev. Soudure, 1961, 17, Jan., 35-43) A technical review, based on the work of the British Welding-Research Association, and proposed as a document for publication by IIS .- s. H.-s

Root welding of heavy duty pipes in low and high alloy steels R. Faulstich (Schweissen Schneiden, 1961, 13, April, 160-165) Methods of root welding with and without inserts are discussed and compared. Advantages and disadvantages of each method are pointed out.

Role of magnetic-flux gas-shielded arc welding R. T. Telford (Weld. J., 1961, 40, March, 237-243) Magnetic-flux welding in a wide variety of industrial applications, with data on equipment, greater range of wires and improved fluxes, is discussed, and its practical and economic advantages are presented.

On welding ferritic-pearlitic steels by the use of austenitic cushioning V. Pilous (Zvár. Sborník, 1960, 9, (4), 439-444) [In Czech] A technology of welding ferritic-pearlitic steels employed up to 500°C is described. Two electrons of the cush of trodes are used, the first one to deposit a mild steel layer, the second to complete the weld with 60/18 NiCr fully austenitic steel. The theoretical reasons for this procedure are discussed, and practical results obtained with it are reviewed.-P.F.

Welding stainless utility steels alloyed with nitrogen K. Löbl and Z. Lehký (Zvár. Sborník, 1960. 9, (4), 445-461) [In Czech] To save Ni 1300, 3, (4), 440-401) [In Czeen] To save Ni a number of stainless steels in which Ni is partly replaced by Mn and N have been developed in Czechoslovakia. Appropriate welding technology is discussed, largely on the basis of the author's own researches.—P.F.

Advances in CO<sub>2</sub> welding with grooved wire de Rop and H. Schmidt-Bach (Schweissen-Schneiden, 1960, 12, Aug., 345-349) A review of the types of wire available and developments in the technology of the method is fol-lowed by a description of some applications.

Manual arc-welding of the Mn-Mo steel 15, **223** O. Hajzler (*Zvár. Sborník*, 1960, **9**, (4), 500-504) [In Czech] The development of electrodes and welding technology employed in welding 75-t boilers are described.—P.F.

Welding steel shapes of large dimensions  ${f J}$ Čábelka (*Zvár. Sborník*, 1961, **10**, (1), 3-20) [In Slovak] Metallurgical, economic and technological problems arising in welding large steel sections made from ingots of up to 50 t are discussed, mainly on the basis of recent work carried out at the Czechoslovak Welding Institute in Bratislava. The influence of N and O2 on ageing is documented by electron micrography. The stress pattern around pre-cipitates was studied by the thin film method, and nitride precipitation by the use of extraction replicas. Precipitation occurs preferentially on dislocations. Nitride precipitation is shown to be complex; unstable nitrides are converted via  $\epsilon$ —Fe<sub>3</sub>N to  $\alpha''$ —Fe<sub>16</sub>N<sub>2</sub>.—P.F.

Spot-welding of low and medium alloy steels G. A. Maslov (Zvár. Sborník, 1961, 10, (1), 21-33) [In Slovak] Spot welding of steels susceptible to ageing on cooling in air is described. Heat-treatment of the weld area by means of currents flowing between the electrodes is shown to facilitate quenching and tempering of the spot, and thus elimination of internal stresses and brittleness.—P.F.

Studies on the 'ferritic' layer formed in the butt-welds of resistance-welded mild steel P. Galan and M. Žitňansky (Zvár. Sborník, 1960, 9, (3), 367-381) [In Slovak] On the basis of extensive experiments the authors come to the conclusion that the view that strong decarburization occurs in the butt-weld zone is unfounded .- P. F

A study of weld cracking of austenitic stainless steels for reactor vessels. (2) Micro-fissure tests H. Suzuki, H. Nakamura, and S. Shimizu (Rep. Nat. Res. Inst. Metals, 1960, 2, March, 253-61: from Japan Sci. Rev. Mech. Elect. Engr., 1960, 7, Aug., 273) [No abstract].

Basic theory of capillary brazing O. Morávek (Zvár. Sborník, 1960, 9, (3), 382-397) [In Slovak] The theory and practice of hard soldering is discussed. Cr. Ag and Al base hard solders standardized in Czechoslovakia are

Recent progress in development of selffluxing, air-proof brazing alloys N. Bredzs and H. Schwartzbart (Weld J., 1961, 40, March, 123s-129s) A progress report is presented of recent work on the development of filler alloys which may be used to braze steel, either in air or in less oxidizing, cheaper, exothermic or endothermic industrial gas atmospheres, with-out flux. The alloys contain lithium and boron which give self-fluxing capability. A theoretical discussion of basic mechanisms, and some experimental results are presented. The most

experimental results are presented. The most promising alloys developed contain ~78%Cu, 20%Zn, 1½%B and 0-½%Li.—s. H.-s.

Alumina lined hump-type atmosphere furace bright brazes and heat treats stainless steel Hi-Temp. Inc (Indust. Heat., 1960, 27, Nov., 2380-2382) This large furnace has a 25im mesh belt, and a hydrogen-controlled atm. maintaining a dew pt. of  $-60^{\circ}$ F. It is rated for  $2100^{\circ}$ F at 195 kW, and treats kitchen sinks, aircraft parts, electronic components etc.

Computer-controlled plate cutting (Shipbuilder, 1961, 68, Feb., 104-105) British Oxygen Ltd in conjunction with Ferranti Ltd, at the request of Messrs. Swan, Hunter & Wigham Richardson Ltd, have designed and installed this unit. The data processing and computer systems are briefly described; when the magnetic tape is played back the recorded trains of pulses are utilized to control the movement of the machine cutting heads. The machine is a port and starboard type capable machine is a port and starboard type capable of cutting two 'mirror image' plates simultaneously (12×40 ft); a max. thickness of 3in is now envisaged. High-speed nozzles cut at speeds some 50% higher than conventional rates. Details of flame control are also given and self-monitoring and 'fail safe' principles and 'fail safe' principles are the control system throughout. are built into the control system throughout.

Cutting weld runners with carbon electrodes and compressed air I. Hrubíšek (Zváranie, 1961, 10, (4), 110–114) [In Czech] The use of

the arc-air torch for cutting weld grooves is described .- P.F.

On the oxy-acetylene cutting of low-alloy age-hardening steels J. Malý, V. Jánošikova, and K. Mazanec (Zvár. Sborník, 1960, 9, (3) 325-344) [In Czech] An analysis was made of the chemical and structural changes occurring in the heat-affected zone as a consequence of oxy-acetylene cutting. On the basis of the results technology was designed for flaw-less cutting of the steels by this method .- P.F.

# MACHINING AND MACHINABILITY

Cast-to-form tooling John Harper & Co. Ltd (Metalw. Prod., 1961, 105, April, 59-61) Most cast-to-form tools are made in a suitable grade Meehanite but for special applications spheroidal graphite cast iron may be employed. The grades of these, their ultimate tensile and compressive strengths, elastic modulus and hardness are tabulated. Heat-treatment, tool design and life are discussed; in general, tolerances of 0.005in are held but in normal practice to leave machining allowances of 32 to in. Where a complex shape is involved, it is generally more economical to produce a castform surface with a nominal filing allowance.

The effect of heat-treatment on the toughness of alloy tools. 2. On the abrasion resisting and non-deformable tool steel SGT and YGT S. Koshira and A. Inata (Hitachi Hyoron, 1960,

As May, 587-90; from Japan Sci. Rev. Mech. Elect. Eng., 1960, 7, Aug., 272) [No abstract]
The selection and heat-treatment of tool steels J. G. Ritchie (J. Australian Inst. Met., 1960, 5, Nov., 264-276) The properties important in a tool steel, and their determination are discussed The various types of tool steel. are discussed. The various types of tool steel are classified according to hardenability and 'hot' hardness, the properties of each grade being reviewed. The principles and practice of heat-treatment are considered, and the importance of surface condition is discussed.

The distribution of machining properties of ferrous materials and its effect on plant operation G. Weber (Werkstattstechnik, 1961, 51, May, 219-223) The scatter of machining properties values in iron goods is surveyed and effects on plant operation are shown to include decrease of production, higher tool turnover, irregular waste accumulation in the polishing department, uncertain storing and ordering and increase in cost of tools.-M.L.

Present-day status of chip-formation research H. Opitz (Microtecnic, 1960, 14, Aug., 158-172) A review of the literature. (59 refs.)

Metal cutting and the built-up nose W Heginbotham and S. L. Gogia (Inst. Mech. Eng., 1961, Advance copy, 3-16) A paper, giving quantitative information about the shape, size, structure, and general behaviour of the 'built-up nose' when machining ferrous materials. Using WC tools on carbon steels, it was found that built-up nose persisted over wide ranges of cutting speed and feed. 'Orthogonal' cutting conditions were used in all cases to reduce the number of geometrical variables to a minimum. Chip-tool-work-piece photo-micrographs were obtained; the various forms of built-up nose so observed were classified, and the conditions under which each type exists were established for the materials used. The effect of cutting speed and feed on size of built-up nose was ascertained, and all results were reduced to one single curve using nondimensional parameters.-\_S.H.-S

The influence rate of strain-hardening in machining P. L. B. Oxley, A. G. Humphreys, and A. Larizadeh (Inst. Mech. Eng., 1961, Advance copy, 3-13) Cutting tests were carried out on a material with a high rate of strain-hardening and on a material with a relatively low rate of strain-hardening. All external parameters of the process such as cutting force, chip thickness ratio, angle of tool-chip interface friction etc., were measured and a slip-line analysis of the plastic-zone was made using strain-hardening slip-line theory. It was found that although externally the process was virtually the same for each material the plastic zones were distinctly different. The relation between the stress distribution in the plastic zone and an independently obtained stress-strain curve of the machined material was clearly shown. Finally new suggestions

were made regarding the nature of the tool-

chip interface contact.—s.H.-s.

Chemical milling C. C. Shepherd (Tech. Proc. Amer. Electroplater's Soc., 1960, 51-54; discussion 229-230) Processes for the controlled removal of metals by direct chemical attack

are described.—A.D.H.

Electroforming M. Rubenstein (Met. Fin.,
Guidebook-Directory, 1960, 28, 426-433) This form of electrofabrication is briefly reviewed and the advantages and disadvantages are assessed. The techniques are summarized. (19

Methods of mechanical processing of cast iron cylinder jackets with the object of improving the regrinding A. Bancila and R. Bancescu (Met. Constr. Masini, 1961, 13, (1), 39-43) A series of mechanical pretreatment operations has been evolved which enables rapid regrinding of cast-iron cylinder jackets, though requiring very accurate machining. The operation sequence is analysed in detail.

Producing leaf springs for road vehicles (Mach. Shop Mag., 1960, 21, Dec., 745-753) Some of the processes used by Richard Berry & Son, West Bromwich, are described. Springs for light cars to truck springs weighing 300 lb are made mostly En 45 (Si-Mn steel) and the output is 12000–13000 springs per week. The various stages, eye-forming, drilling and reaming, tapering the leaf ends, assembly of leaves. passage through the furnace quenching and tempering; in this latter process, the springs are reassembled inside out and temporarily clamped together. Testing and the final stages are described .- c.v

Leaded steel N. Sekiguchi, Y. Ishikawa, and T. Iwai (J. Japan Mech. Engrs., 1960, 63, May,

T. Iwai (J. Japan Mech. Engrs., 1900, 03, May, 723-29; from Japan Sci. Rev. Mech. Elect. Engr., 1960, 7, Aug. 272) [No abstract]. Electrochemical micromachining of iron whisker surfaces B. C. Banerjee and P. L. Walker (J. Electrochem. Soc., 1961, 108, March, 262-265) An electron microscopical study was added to take patterns of iron whiskers; it is made of etch patterns of iron whiskers; it is suggested that contamination films formed on the whisker edge can be removed by HCl (0.2-2.0 pH); this results in a highly active, smooth surface but at a higher pH this is not produced. Whether this is the result of insolubility or formation of a new protective film is discussed. HCl+chromic acid, CuCl<sub>2</sub>, FeCl<sub>2</sub>, or NO<sub>3</sub> ions will produce a very smooth surface with pointed tips. The growth mechanism of metal whiskers is discussed in the light of the experimental findings.-c.v.

## CLEANING AND PICKLING

Solvent vapour degreasing H. Nulle (Met. Fin., Guidebook-Directory, 1960, **28**, 225-227, 230, 232, 236, 238) A general review.—c.v.

Faraday's Laws applied to cleaning A. K. Graham (Tech. Proc. Amer. Electroplater's Soc., 1960, 41-44) Examples are given of the application of Faraday's Laws to determine conditions for anodic and cathodic cleaning processes. --- A. D. H.

Choice of preparation method D. G. Cox (Corros. Prev. 1961, **8**, April, Corros. Engr. VI-VII) Blasting, flame descaling and chemical removers, power tools and hand tools are briefly discussed and their efficiency is indi-

Molten caustic de-sands cylinder heads (Metalw. Prod., 1961, 105, April 5, 54-55) Diesel engine cylinder head at the Farington foundries of Leyland Motors Ltd, now undergo supplementary de-sanding in a self-contained pickling plant, molten NaOH at 500° being used. There are four stages to this process, pre-heating, pickle de-sanding, cooling and washing. A layout of the process is shown a brief description is given and the safety precautions are stressed.—c.v.

Scale on wire rod and its removal by mechanical means. II S. Garber and G. M. Sturgeon (Wire Ind., 1961, 28, April, 369, 371–373, 375–376) Low, 850, 950° and high temp. scales (x 200) are compared. Some 26 samples 5gauge rod, high-medium and low-C steels were examined; the thickness and wt of scales are recorded and the structure of the residual scale is examined and to confirm the hypothesis that residual scale contained a higher proportion of the higher oxides a Vickers micro-hardness

tester was used. It was considered that these would be more detrimental to die wear than the low-temp. residual scales. Hematite, gave a reading of 1030 DPH, magnetite, Fe<sub>3</sub>O<sub>4</sub>, 420-500 and wustite 270-350. The efficient removal of scale mechanically depends on these factors (temp. of formation, nature and amount of oxide) and this is to be the subject

of a further communication.—c.v.

Polishing and buffing H. L. Kellner (Met. Fin. Guidebook-Directory, 1960, 28, 130, 132, 134-138, 140, 142-152) A general descrip-

tion; 23 case studies are given.—c.v. Electropolishing J. F. Jumer (Met. Fin., Guidebook-Directory, 1960, 28, 455-456, 458-467) A general description.—c.v.

The effect of surface preparation on oxide films on Gr and Fe-Gr alloys D. Caplan, A. Harvey, and M. Cohen (J. Electrochem. Soc., 1961, 108, Feb., 134-138) The oxide film left on Fe-Cr alloys by electropolishing gives a much higher initial reaction rate in high-temp. oxidation than is found with other surface preparations. Cathodic reduction, after electropolishing and other strongly oxidizing treatments, gives an anomalous curve with a sharp min. This is interpreted as due to surface oxide of high reduction overvoltage and even higher  $H_2$  overvoltage. It is suggested that  $Cr^{6+}$  in a nonstoicheiometric Cr<sub>2</sub>O<sub>3</sub> film is cathodically reduced to Cr<sup>3+</sup> with a corresponding decrease in cation vacancy constitution. In acid etching of electropolished Cr alloys the same peak occurs in the potential/time curve. Surface preparations for alloys exhibiting passivity are sensitive to time intervals between operations and therefore standardization is essential

Pickling of iron and steel in technical phosphoric acid M. Apperloo and H. Benninghoff (Metall Reinigung Vorbehandlung, 1961, 10, April, 49-57) The pickling process for iron and steel is analysed from theoretical, practical and economical viewpoints, demonstrating that the most advantageous process is the one in which  $H_3PO_4$  (techn.) is the pickling agent, coupled with a continuous cation-exchange regeneration circuit. The various advantages

are enumerated .- M.L.

Inhibition of hydrogen embrittlement during **pickling** R. H. Anderson (PB152680, [1957] pp.17; AD136254; from US Res. Rep., 1961, **35**, Jan. 13, 92) Steel 1095 reacted with 4.8 N HCl inhibited in DHQ, hexamine or both was studied. p-Toluidine and hexamine was no better, acetaldehyde was not as good in inhibiting embrittlement.—c.f.c.

### PROTECTIVE COATINGS

Plating room layout G. R. Kentta (Met. Fin., Guidebook-Directory, 1960, 28, 17, 20, 22–23, 25–26) Still tank cleaning and plating, semiautomatic plating, trolley hoist systems, fully automatic cleaning and semi-automatic plating

automatic cleaning and semi-automatic plating and a fully automatic layout is discussed together with the relevant problems.—c.v. Immersion plating N. Hall (Met. Fin., Guidebook-Directory, 1960, 28, 451-455) The formulae are given for the deposition of the various metals on Al, Cu-alloys, steel, etc. Technical developments of 1960 N. Hall (Met. Fin., 1961, 59, Jan., 36B-36K, 93) The literature of metal finishing is reviewed. (386 refs).—A.D.H.

Thirty-five years of outplating experience. II (Metal Fin., 1961, 7, March, 101–107) The plant and techniques used at the Battersea plant of the Atlas Plating Works Ltd are described. The treatment and disposal of effluent is also included .- c. v

Solution transfer in barrel plating P. Glab, R. S. Modjeska, and S. P. Gary (*Tech. Proc. Amer. Electroplaters*' Soc., 1960, 184–187; discussion 251–253) Quantitative studies of solution transfer in barrel plating are des-

eribed.—A.D.H.

Measurement of control of local current densities and rate of deposition respectively in a galvanic bath W. Huber (Microtecnic, 1960, 14, Aug., 181–187) A newly-developed current density meter of Swiss origin is described, by which the progress of deposition can be measured directly in  $\mu/\min$  and results are

Nomograph on thickness of electrodeposits (Met. Fin., Guidebook-Directory, 1960, 28, 653-654) This is based on a 100% current efficiency and hence the actual plating time will be greater .-

Science for electroplaters: 62. Adhesion tests L. Serota (Met. Fin., 1960, **58**, Dec., 65–67; 1961, **59**, Jan., 49–50) Methods of quantitative measurement of the adhesion of metal coatings are described .- A.D. H.

Automatic pH and redox control Y. Mattock and A. W. Uncles (Prod. Fin., 1961, 14, Jan., 79-82) The essentials of pH control and sources of error (temp, glass and reference electrodes) are indicated. The principles of instrumental redox control are outlined and the oxidation potential of metals is given, a typical redox electrode construction being illustrated, this being used with a reservoir-fed reference electrode. (Feb., 70-76) The discussion on the destruction of cyanide and chromate wastes is continued. The various treatments and their rationale are discussed the appropriate ex-

planatory graphs are included.—c.v.

Solutions of electrolytes J. C. Poirer (Ann. Rev. Phys. Chem., 1959, 247-272) Some 253

papers are quoted and discussed.—c.v.

Measuring loads for steel nuts G. C. Field (Met. Fin., 1960, **58**, Dec., 61–63) Nomographs are presented for calculating the surface areas of hexagonal nuts for plating purposes

The effectiveness of metallic undercoats in minimizing plating embrittlement of ultra high strength steel W. Beck and E. J. Jankowsky (Tech. Proc. Amer. Electroplater's Soc., 1960, 152–159; discussion 246) The H<sub>2</sub> embrittlement of AISI 4340 steel caused by Cr and Cd plating was substantially reduced by first plating with pyrophosphate copper or Watts nickel or by Cd plating with a fluoborate bath instead of

a cyanide bath.—A.D.H.
Applying statistical quality control to plating processes R. W. Steinmetz (Tech. Proc. Amer. Electroplater's Soc., 1960, 45-50: discussion 228-229) The application of statistical quality control charts to the composition and performance of plating processes is described

Hazards in the plating room W. R. Meyer (Tech. Proc. Amer. Electroplater's Soc., 1960, 55–58) Causes of explosives and fires and the dangers associated with chemicals used in metal finishing are discussed.—A.D.H.

Factors in bright nickel plating. Some

essential rules G. Bacquias (Galvano, 1960, 29, June, 337–340) A short survey, comprising pH, cationic and anionic concentration, density of current, heating and agitation, skinning agents, levellers, with final insistence on bath purification .- s. H

Kanigen—a chemically deposited nickel alloy coating (I) General American Trans-portation Corp. (Metalloberfläche, 1961, 15, March, 91-94) A description of the chemical composition, the physical and mechanical properties, and the characteristic features of Kanigen, especially adherence and corrosion behaviour. (II) (April, 122-124) Applications

and application technique are reported.—M.L. Physico-chemical bases of the chemical nickel-plating process K. M. Gorbunova and A. A. Nikiforova (Fiziko-Chimicheskie osnovy protessra khimicheskogo nikelirovaniya, Moscow, 1960, pp.207) This book generalizes the results of investigations concerning conditions under which the chemical nickel-plating process takes place, the mechanism of the reactions, and the properties of the coatings formed. The author's own results and those of other workers are presented. As there is a lack of literature on the industrial application of the process, a certain amount of attention is paid to technological aspects (90 refs). Gertain information from the history of investigations in the field of the reducing effect of hypophosphite on the salts of heavy metals (7-15) Certain chemical data are given; of interest as background information in the study of the chemical nickel-plating process. Conditions for the formation of nickel coatings in an acid medium (16-43) Questions studied comprise the effect of the nature of the metal covered, the effect of individual factors on the rate of nickel reduction, the coefficient of utilization of hypophosphite, and the effect of certain additions to the solution on the process of nickel reduction. Ways of intensifying the nickel-plating process (45-68) Methods discussed are those given in the literature, rate of

the process as a function of the ratio of hypophosphite concentration to buffer addition, the effect of complex generators on the process of nickel reduction, an investigation of the process of nickel reduction with increased centration of hypophosphite, and methods of regenerating the nickel solution. Certain data on the source of the nickel plating process in alkaline solutions (69-78) The literature is reviewed and many of the results are presented in tabular form. Properties of nickel coatings (79-121) Properties studied are physical, chemical, and magnetic; hardness; hydrogen content of chemically reduced nickel; adhesion; brittleness; wear-resistance; mechanical prop erties of steel subjected to chemical nickel plating; and porosity, protective properties, and evenness of coatings. Structure of deposits formed in the chemical nickel-plating process (122-132) Literature is reviewed. Structure has been examined using photomicrographs, electron microscopy, and X-ray analysis. No final conclusion on the nature of structures was reached, but understanding of the unique properties of Ni coatings has been increased. Questions of the mechanisms of the reduction reaction of nickel with hypophosphite (134-150) Questions considered are special features of the chemical nickel-plating process; development of theories for the mechanisms of the reactions of reduction by hypophosphite; mechanism of the process, including the stage of reduction by atomic hydrogen; reaction mechanisms of hypophosphite decomposition; and mechanism reduction reaction of phosphorus with formation of phosphides. Certain data on industrial use of the chemical nickel-plating process (151-176) Data are presented on methods of carrying out the chemical nickelplating process, equipment for the process, fields of application, and technical and economic aspects. Concerning methods of analysing solutions for hypophosphite and phosphite content in the chemical nickel-plating process (177-182) Methods described are the determination of phosphite, the simultaneous oxidation of hypophosphite and phosphite using bromate-bromide (first variant) and iodine (second variant), and determination of hypophosphite by other methods. Certain data on the application of nickel coatings to non-metallic surfaces (183-193) Data are presented in relation to (a) the creation of electrical or thermal conducting surfaces, (b) producing surfaces to which other metals can be applied, (c) producing a base for the subsequent electrodeposition of metals, (d) producing a surface through which moisture will not pass, and (e) increasing wear-resistance of a surface. Conditions for the formation of cobalt and nickel-cobalt coatings in the chemical nickelplating process (194-202) Descriptions are given of the reduction of cobalt salts and of the simultaneous reduction of nickel and cobalt salts. Certain information is also given on the magnetic properties of cobalt and nickelcobalt deposits.—A.I.P Recent developments in nickel/chromium

plating. I G. F. Lee (Products Fin., 1961, 14, May, 83-84, 148) A quality-label scheme, supported by the British Non-Ferrous Research Association, the British Standards Institution, and the Mond Nickel Company Ltd, is described and the advantages of such a

labelling system are stressed.

Galvanised coatings for welded components
Ruge and P. Hildebrandt (Schweissen Schneiden, 1961, 13, May, 195–199) The protection against corrosion of weld seams by means of galvanized coatings has been studied, determining the optimal compositions and process conditions. It is shown that some defects of the welds can be corrected for the purpose of effective galvanizing by proper choice of solutions or special pickling.—M.L.

The hot-dip galvanizing of grey cast iron P. Debouté (Korrosion, 12, 1960, 177-179) [In German] It is shown that coatings of 600–900 g/m² can be obtained in 2-3 min at 450°C.

Installation for the continuous zinc plating of tubes V. P. Markova, Z. E. Frienekmana, V. D. Zhernovskogo, R. V. Rodzherca, and N. I. Lamonova (Stal', 1961, (5), 439; Russ. Patent 123381) A diagram, with a brief account and a key to the parts shown.

Comparative field tests to determine the

corrosion resistance of electrodeposited zinc coatings passivated by various chemical methods T. Biestek (Korrosion 12, 1960, 189-195) [In German] The results of three years' exposure tests on these coatings are reported and assessed. No satisfactory agreement was found between the results of exposure and accelerated tests (10 refs).

Electrodeposition of tin from the potassium stannous pyrophosphate bath V. Sree (J. Sci. Indust. Res., 1961, 20B, Jan., 18-22) This reagent has been used in the place of  $\mathrm{Na_4P_2O_7}$ form a complex and the advantages are indicated, cathode efficiency, speed in plating, bath voltage, resistivity, throwing power, and anode control.-c.v.

Continuous measurement of tinplate thickness Applied Research Laboratories Inc. (Tin, 1961, No.51, 3-4) The operation of the 'Quantrol' X-ray spectrometer, which relies on analysis of the fluorescence radiation emitted by the tinplate strip while travelling under a beam of X-rays is briefly described. Accuracy to within  $\pm 1\%$  is claimed.—s.H.-s.

Iron plating from the sulphamate bath S. S. Misra and T. Misra and T. L. Rama Char (J. Sci. Indust. Res., 1961, 20D, Jan., 43-44) The effect of variables (electrolyte concn., temp., and agitation) has been studied to obtain satisfactory plates up to a current density of 12 amp/dm<sup>2</sup>.

Concerning the possibility of the electro-deposition of alloys of vanadium with iron A. M. Kunaev (Izvest. Akad. Nauk Kazakhakoi A. M. Kunaev (Izvest. Akad. Nauk Kazakhakoi SSR, Seriya metallurgii, obogashcheniya, i ogneuporov, Issue 2 (8), Alma-Ata, 1960, 52-54) The process of electrodeposition of V in the form of an alloy with iron is quite feasible from solutions of salts of the metals. Solutions obtained after working the primary vanadium stock can be subjected to electrolysis.

Laboratory screening tests of sprayed linings for chemical process equipment R. S. Foster (Corrosion, 1960, 16, Nov., 26–28, 32) The author gives detailed results of laboratory immersion tests to screen coatings for equipments of the control of the coating for equipments of the coating for equipments. ment protection. The importance of such tests and of pilot-plant environment tests is discussed, and a survey is made of the relative costs of coatings and of clad materials.—G.F.

The effect of ionic nickel in hot zinc phos-

phatizing solutions P. G. Chamberlain (PB 152294, Feb. 1959, pp.13; Rept. No. 59-492; AD 210922; from US Res. Rep., 1961, 35, Jan., 13, 75) The effect of nickel-ion additions to hot zinc phosphatizing baths on coating weight, corrosion resistance and texture of coating was determined. It was found that as as 20% increase in coating weight resulted. A slight improvement in corrosion resistance was noted. The texture of the coating was somewhat coarser than the control without nickel.—c.F.c

Plastic-coated sheet H. Groebler (Mitt. Forsch. Blech., 1960, (17), 211–223) An outline of the history of the development of plastic coated sheet is followed by a review of plastics used, manufacture, treatment and field of application of the material. Economic factors

are discussed. (42 refs.)

Adhesion of organic enamels to electrodeposited nickel F. X. Carlin (Tech. Proc. Amer. Electroplaters' Soc., 1960, 59-62; discussion 231-232) Adhesion tests of an oleoresinous enamel on nickel and nickel oxide surfaces showed that nickel deposit provides a receptive surface for organic finishes. Freshly plated surfaces are unsatisfactory but ageing in air or various conversion coatings give good adhesion .- A.D. H.

Tetrafluoroethylene-lined pipe has lower installed cost than other high temperature piping T. R. Thierry (Corrosion, 1960, 16, Nov., 9-12) The author discusses the reduction in installation costs of polytetrafluoroethylene (TFE)-lined steel piping compared with glass-lined and alloy piping. The manufacture of TFE-lined pipe is described and instances of its application are given .- G.F.

Glass linings and vitreous enamels R. Mc-Farland (Corrosion, 1960, 16, Dec., 615t-621t) A detailed account is given of the properties, applications, and limitations of glass linings and porcelain (vitreous) enamels for metal structures.-G.F.

Electricity for paint stoving and vitreous enamelling J. T. Sharples (Prod. Fin., 1961,

14, Jan., 68-70, 73-78) Convection, box and other type ovens for paint stoving are considered and various furnaces are discussed. An indication is given as to loading, temp. etc.

The purpose, theory and application of nickel dip N. C. S. Millar (Metal Fin., 1961, 7, Feb., 49-55) A discussion. Methods of analysis are included .- c. v.

Organic coating formulations (Met. Fin., Guidebook-Directory, 1960, 28, 535-536, 538-539) A brief summary dealing with pigments and transmission of u.v. light by these, solutions of the coating of the vents and surface active agents.—

Painting of welds J. D. Keane and J. Bigos (Corrosion, 1960, 16, Dec., 601t-607t) To determine methods of improving paint performance on the welded areas of steel structures, exposure tests have been made on 1146 welded, treated, and painted specimens. The most important result is that the electrode coating should be removed from the weld area, preferably by blast cleaning, before painting.

Antifouling properties of pesticidal materials S. Miller (PB 150768, Monthly progress rept. for May-June 1959, pp.7; ML 59137; from US Res. Rep., 1961, 35, Jan. 13, 74) The purpose of this programme is to evaluate the effectiveness of various experimental and effectiveness of various experimental and proprietary pesticides as antifouling toxicants. The screening test technique which is employed will qualitatively classify the effectiveness of the pesticides for control of the various forms of fouling organisms. The first rack of 19 panels was exposed on 19th May 1959. When the panels were inspected after 10 days, fouling organisms were present on the control panel and on 15 test panels. Three panels were completely free of fouling. This group has not yet completed a full thirty day test period. Six additional racks of 19 panels each have since been exposed. (PB 150770, Monthly progress rept. for 1959, July, pp.8; ML 59182; from US Res. Rep., 1961, 35, Jan. 13, 74) The effectiveness of the chemicals in preventing attachment of the various fouling organisms fouling organisms were present on the control attachment of the various fouling organisms is listed in descending order of effectiveness. 84 of the 144 chemicals tested were completely ineffective, and have not been included in the table. (PB 150771; Monthly progress rept. for 1959, Aug., pp.7; ML 59211; from US Res. Rep., 1961, 35, Jan. 13, 74) 94 of the 144 chemicals tested were completely ineffective, and have not been included in the table. (PB 150772, Monthly progress rept. for 1959. Sept., pp.9; ML 59230; from US Res. Rep; 1961, **35**, Jan. 13, 74) 25 of the 36 chemicals tested were completely ineffective, and have not been included in the table. Confirmatory tests have been conducted on 36 chemicals; results of the confirmatory test are shown immediately below results of the test of each chemical. (PB 150773, Monthly progress rept. for 1959, Oct; pp.8; ML 59242; from US Res. Rep., 1961, 35, Jan. 13, 74) Six of the 18 chemicals tested were completely ineffective, and have not been included in the table. and have not been included in the table. Confirmatory tests have been conducted on 72 chemicals. (PB 150774, Progress rept. for 1959 Nov.-Dec., pp.13; ML 60020; from US Res. Rep., 1961, 35, Jan. 13, 74) The effectiveness of the chemicals in preventing attachment of the various fouling organisms is listed in descending order of effectiveness. Thirty-six of the chemicals tested were completely ineffective, and have not been included in the table. Confirmatory tests were conducted on 90 chemicals. (*PB* 150775, *Progress rept.* 1959 Jan.-Feb., pp.10; from *US Res. Rep.*, 1961, **35**, Jan. 13, 74) The effectiveness of 36 chemicals in preventing attachment of the various fouling organisms is listed in descending order of effectiveness. Twenty-two of the chemicals tested were completely ineffective, and have not been included in the table. The first evaluation of 36 new chemicals was conducted during the present report period. Descriptions of the chemicals and results of the test follow. Nine of the chemicals were completely ineffective, and have not been included in the table of results. Confirmatory tests were conducted on 18 chemicals .-- C.F.C

# CLAD SHEET AND HARD FACING

Metallic diffusion coatings R. L. Samuel (Chem. Ind., 1961, March 18, 337) A lecture,

comparing various methods of chromizing steel, whereby the coating becomes an integral part of the steel and can be heat-treated oven forged, in the data on temp. limitations, followed by a brief discussion.—s. H.-S.

Correct utilization of weld-surfacing materials and their metallographic features J. Žák (Zvár. Sborník, 1960, 9, (4), 471–479) [In Czech] The principles underlying the choice of weld-surfacing alloys in various applications are considered .- P. F

The development of an electrode for automatic weld-surfacing in the metallurgical industry L. Lakatoš (Zvár. Sborník, 1961, 10, (1), 109–148) [In Slovak] The development and use of a tubular electrode for automatic submerged arc-welding in hard-surfacing is described .-- P. F.

## POWDER METALLURGY

Studies on the morphological properties of iron particles prepared by reduction of iron salts T. Takada and T. Hayashi (J. Japan Soc. Powder Met., 1959, 6, Dec., 223–237) Reducing oxides from oxalate, hydroxide, sulphate and formate or direct reduction of the salts at 400, 600 and 800°C gave powders which were examined with the optical and electron microscopes. All were small aggregates of particles. Their characteristics depending upon the source are described.

Surface diffusion during sintering of unpressed powders K. Torkar and H. Neuhold (Z. Metallk., 1961, 52, April, 209–215) The method used for producing the powders is given, followed by results of magnetic measurements of the surface diffusion of Cu in Nisurface diffusion is shown to play a prominent part in sintering. Activation energies of diffusion processes are calculated and shown to be related to lattice energies within given limits. The diffusion constant for a material can be calculated by means of an extended Arrhenius equation. -R.P

Magnetic properties of sintered iron H. Dietrich (Z. Metallk, 1961, 52, April, 232–235) Experimental results on magnetic properties commercial, unalloyed sintered iron are discussed. Magnetic properties are shown to discussed. Magnetic properties are snown to improve by heat-treatment. Annealing at  $1200^{\circ}\mathrm{C}$  for 2 h in an atmosphere of  $\mathrm{H_2}$  is recommended. The following values were obtained: coercive force  $\leq 20$ , initial permeability  $\leq 300$ , maximum permeability  $\leq 2000$ , magnetic ageing below 5%.—R.P.

Theories of sintering with regard to effects during the production of thermoelectric materials by powder metallurgy. I. Theory of sintering H. Schreiner and F. Wendler (Z. Metallk., 1961, 52, April, 218-223) Opinions of various investigators on the theory of sintering are compared critically. The diffusion of vacant lattice sites has to be taken into account when considering the sintering of

semi-conductors. (85 refs.)—R.P.
Sintering theories with regard to effects during the production of thermoelectric materials by powder metallurgy. II. Experimental methods and results H. Schreiner and F. Wendler (Z. Metallk., 1961, 52, April, 224-228)
The processes occurring during production of thermoelectric materials by powder metallurgy are discussed in relation to the structure obtained, this is characteristics. tained; this is shown to have a decisive effect on thermoelectric properties. The influence of sintering temp, and compacting pressure on the density are dealt with. A decrease in density was observed under certain operating conditions .- R.P.

# PROPERTIES AND TESTS

The philosophy of material testing F. G. Tatnall (Mechanical Properties of Metals – A short Course', Pennsylvania State Univ., 1958, 31-34) A brief commentary on the necessity for, and the outlook upon, the testing of materials. Recent developments in testing machines and related instrumentation I. Jensen (277-284) A report. II. B. L. Lewis (285-296) A report. Mechanical properties of metals A. N. Freudenthal (1-29) The physical origins of mechanical properties, concepts of structure, order and disorder - mobility, structural imperfections, types of deformation and structure, strength, mechanical behaviour and

mathematical idealization, three dimensional states of stress, the significance of mechanical testing and the interpretation of results are succintly discussed .-

Some physical properties of martensitic stainless steels J. G. Hoag and D. B. Roach (PB 161218, 1960, Sept., pp.31; DMIC Memo 68; from US Res. Rept., 1961, 35, Jan. 13, 92) [No summary]

The principal mechanical properties of rimming arsenic MSt 3kp steel I. G. Kazantsev, G. G. Lukashov, M. T. Bul'skii, L. P. Tarasova, and N. F. Sapelkin (StaP, 1961, (4), 348-350) The superiority of the As-containing grades is shown in tensile, fatigue, impact and

weldability tests

Yield condition for a plate of anisotropic material J. F. Bratt (Tek. Uke., 1961, 108, Jan. 12, 33, 34, 35) Using a modified Tresca's yield condition which incorporates the aniso-tropic properties of a material (J. Franklin Inst., 1958, 265, (3)), critical loads for a circular plate of anisotropic material, with clamped out edge loaded uniformly, are discussed, and a curve is plotted showing the influence of degree of anisotropy between zero and unity on the strength of the plate. Plate deflection is determined, using associated flow

A customer surveys reliability factors in steel usage H. T. Hallowell, jun. (J. Met., 1960, 12, Dec., 933) An extract from a paper read at the Annual AIME Electric Furnace Conference, which discusses specifications and inspection.

Physical and chemical properties of surfaces J. M. Honig (Ann. Rev. Phys. Chem., 1959, 77–102) A review with 290 references.—c.v.

Flatness measurements on sheet G. Oehler (Mitt. Forsch. Blech., 1960, (17), 223–224) Shortcomings in new standards with respect to flatness tolerances are indicated, and recommendations for modifications to DIN 1541 are put forward.

Testing the precision of electrical instruments for the measurement of surface roughness E. Bickel (Microtecnic, 1960, 14, Aug., 149–157) Accuracy tests carried out with various instruments at the machine tool laboratory of the Federal Polytechnic School at Zurich are

described and discussed.

'Indicators' which show the technological plasticity of the material T. Peleynski (Obrobka Plastyczna, 1959, 1, (2), 7-22) No single sign or findings will give the complete answer to the question of suitability of the material for cold working: plastic resistance, S, characterizing the mechanical resistance during the working process, the resistance of the material, r, to reach the plastic state which expresses the ability to withstand large strains without fear of fracture, the deformability of the material which is indicated by the necking ratio in a simple tension test and m which characterizes the mode of fracture at the neck in a simple tension test.-c. v

Poisson's ratio for metals and alloys W. Köster and H. Franz (Met. Rev., 1961, 6, no. 21, 1-55) A comprehensive review is presented under eight principal headings: I. Elastic-theory relationships. II. Methods for deter-mining Poisson's ration (PR). III. PR for pure metals. IV. Dependence of PR on composition and heat-treatment of alloys, V. Dependence of PR on working, VI. Temperature-depend-ence of PR, VII. Stress-dependence of PR. VIII. Relationship of PR to other physical

quantities. (132 refs).—s. H.-s.

The effect of grain size on the stress-strain curve of  $\alpha$ -iron and the connexion with the plastic deformation of the grain boundaries H. H. Tjerkstra (Acta Met., 1961, 9, April, 259-263) Experimental data are presented with respect to the grain size dependence of the yield stress of decarbonized (and denitrid-ed) mild steel under uniaxial load, from which data with the aid of dislocation theory an estimate is made of the grain boundary stresses. The magnitude of these stresses suggests that during plastic deformation dislocations do not stop at a grain boundary but slip across it into the adjacent grain. A comparison of the boundary stress which occurs at a low value of the strain in the case of decarburized α-iron with the lower yield point in the case of mild steel (Hall) suggests that the presence

of carbon and nitrogen may considerably enhance the strength of the grain boundaries.

Role of crystal structure in the ductility of

pure iron at elevated temperature J. L. Robbins, O. C. Shepard, and O. D. Sherby (*JISI*, 1961, **99**, Oct., 175–180) [This issue].

199. Oct.

The dependence of the flow stress of Fe3Al on crystallographic order A. Lawley, E. A. Vidoz, and R. W. Cahn (Acta Met., 1961, 9, April, 287–296) Polycrystalline tensile samples iron alloys containing 24.8, 25.5 and 27.8 % Al were equilibrated and quenched from various temp. into oil or water, and the flow stress determined. A single sample was used for a complete series of tests; by using small strains and giving an appropriate recovery treatment, the effect of each tensile strain was removed before the next treatment. Maximum in the flow stress were in each case found for quenching temp. at or near the critical ordering temp. In another series of tests on the 24.8% alloy, the flow stress was measured as a function of isothermal annealing time at 440°C for the initially disordered alloy, and a peak flow stress was found for annealing times of about 5 min. Some exploratory experiments are also reported on the hardness of a short range ordering alloy containing 19.4 at-% Al Existing theories of order hardening are reviewed and their applicability to the present results is discussed.—s. H.-s

Application of internal friction measurements to the study of gases in metals G. M. Leak (ISI Special Report, (68), 1960, 270-295) A brief review of the mechanism of damping and its measurements obtained with the torsion pendulum. The results obtained are discussed in relation to  $N_2$  in iron, effect of other elements on  $N_2$  in iron, the Si–Fe–N alloys and  $H_2$  in iron. A summary is also provided of the damping measurements in other body-centred cubic metals and the damping due to interstitials in face-centred cubic metals. Grain boundary damping is also examined with special reference to further research.—c.v.

Plastic behaviour of metals under simple and combined stresses E. A. Davis ('Mechanical Properties of Metals – A short course'. Pennsylvania State Univ., 1958, 91–110) This problem is mathematically discussed.—c.v.

Hot ductility of stainless steels during weld thermal cycle. 2. On AlSI 347, 304, 3041 stainless steels H. Suzuki, T. Bada, and H. Nakamura (Rep. Nat. Res. Inst. Metals, 1960, 2, March, 239-52; from Japan Sci. Rev. Mech. Elect. Engr., 1960, 7, Aug., 273) [No abstract].

The thickness of spring steel and its effect on the mechanical properties S. I. Doroshek (Stal' 1961, (2), 171–172) Clock springs made from rolled EI 142 steel showed austenite contents increasing with degree of reduction, also with high-hardening and low-tempering temp. A single optimum thickness of 0.33-0.34 mm is recommended for all springs.

Contribution to the study of the factors which improve the modulus of elasticity of cast irons A. Sole Amat (Inst. Hierro Acero, 1960, 8, Oct.—Dec., 835–846) [In Spanish] A series of experimental casts have been studied to establish the relationship of the modulus of elasticity with respect to variations in cooling rate, composition, and graphite content. The modulus of elasticity is shown to be an import ant criterion of quality. This modulus depends on the graphite structure which in turn depends on the graphite content and cooling rate (13 refs).—P.S

Influence of the chemical composition on the structure and mechanical characteristics of a 13%Cr martensitic steel P. Virdis (Fonderia Ital., 1961, 10, (2), 43-47) [In Italian] It is concluded that the deficiency in the resilience value induced in a 13%Cr martensitic steel casting by excessively high Si content can be only partially reduced but not entirely elimin-This is mainly due to the fact that the composition of the steel does not permit elimination of the ferritic constituent by heattreatment and only allows it to reach a minimum level at a certain temp. For the material tested the best resilience values were reached at 1150°C

On the internal friction of cold-worked and quenched martensitic iron and steel T. Mura, I. Tamura, and J. O. Brittain (J. Appl. Phys., 1961, 32, Jan., 92-96) A theoretical explana-tion is given for the internal friction peaks which are observed at 200-250°C for worked iron and steels and for steels in the martensitic condition. The theory for the peaks is based upon the addition of a term to the free energy in order to account for the strain energy due to the interaction of an atmosphere and the line imperfections. The standard linear solid was obtained from the model in which dislocations are vibrating with an atmosphere of carbide precipitates.—C.F.C.

Dislocation networks in a low-alloy steel A. S. Keh (J. Appl. Phys., 1960, 31, Aug., 1501-1502) A letter. Available published work is briefly mentioned; the present note relates to a steel with 1%Cr, 1%Mn, and 0.4%C. This was first hot-rolled to 0.03in and subsequent heat-treatment consisted of quenching from the austenite region and then tempering at 667° for 24 h, or at 718° for 72 h. The method of obtaining thin sections is described and the microstructure studied. The origin of the networks observed is unknown; it is presumed they were introduced during the transformation to martensite or more probably during the first stage of tempering; at the later stage they probably rearranged themselves into stable networks with a lower energy. The dislocation reactions involved in their formation are being analysed.—c. v.

Some new observations on the origin, nature and configuration of slip bands H. J. Latière and R. M. Michaud (Rev. Mét. Mém. Sci., 1960, 57, Dec., 923–929) Various types of grouping of the slip bands in an Al single crystal and various interactions between the adjacent large crystals of a group are examined.

On the origin of dislocations in solids. Some aspects of sources encountered in metals A. Fourdeaux and A. Berghezan (Compt. Rend., 1961, 252, March 6, 1462–1464) A note, claiming to present some important new sources of dislocations in metals.—s. H.-s.

Estimation of equilibrium vacancy concentration in solid metals R. F. Mehl, M. Swanson, and G. M. Pound (Acta Met., 1961, 9, March, 256-257) A letter, with a table of the experimental and calculated enthalpy of formation of vacancies in solid metals, in which values for α≡g/b are listed. For Fe (b.c.c.), solidification shrinkage is given as  $0.03\pm0.005$ , enthalpy of fusion as 3.67, and calculated enthalpy of formation as 49.—s. H.-s.

Effect of grain size and temperature on slip, twinning, and fracture in 3% silicon iron D. Hull (Acta Met., 1961, 9, March, 191-204) Most of this work was carried out at the Atomic Energy Research Establishment, Har-Tests were made on Si-Fe showing brittle fracture behaviour, due to twinning, over a range of grain sizes when tested at -196 and  $-253^{\circ}$ C, also at high temp, where the normal yield point and lower yield elongation specimens being examined metallographically after fracture to determine the incidence of twinning. In specimens with d-1=18, tested at -196°C, appreciable twinning occurred all along the gauge length, being most pronounced in the larger grains. The thickness of the twins increased with decreasing grain size and with increasing temp. between -253 and  $-196^{\circ}\mathrm{C}$ . The size of the crack nucleus was calculated from the thickness of the twin and the twinning shear assuming that the crack formed at the intersection of twins and the value compared with the critical size required for propagation as a brittle crack according to Cottrell's theory of brittle fracture.—s. H.-s.

The Peierls-Nabarro force and the deformation of iron and steel N. Louat (Aust. J. Phys., 1960, 13, July, 309-315) Evidence for the existence of this force was examined. It was concluded that observed behaviour is unlikely to follow from the present proposed mechanism of this force and that the observed frictional stress may arise as a consequence of dislocations being in pile-ups.—R.S.F.C.

Direct electrical integration of closed calibration curves and their application to the measurement of the damping of metals and the indicating of piston engines H. H. Emschermann (VDIZ, 1961, 103, Feb. 11, 169-176) By means of the method described, the required values can be recorded direct over a practically unlimited frequency range. For example, the damping of a material in the work content of an indicator diagram where there are variables, such as temp., stress, load, speed, etc., can be plotted direct

Relative thermodynamic properties of solid iron-aluminium alloys S. V. Radcliffe, B. L. Averbach, and M. Cohen (Acta Met., 1961, 9, March, 169-176) The relative thermodynamic properties of solid Fe-Al alloys were obtained at ~900°C by emf measurements, using a molten chloride electrolyte. The heats of mixing are large and negative, with H<sup>M</sup>= -8200 cal/g atom at 50 at-%. Large negative entropies of mixing were also observed, with 1.8 e.u. at the equiatomic composition, The negative entropy changes are discussed in terms of magnetic, vibrational, and electronic effects .- s. H.-S

Enthalpy and specific heat of nine corrosionresistant alloys at high temperatures T. B. Douglas and A. C. Victor (J. Res. NBS, Eng. Instr., 1961, 65C, Jan.-March, 65-69) Specific heats from 0-900° are reported for two alloys 90 Ni-10 Cr and stainless steel type 316; this is considered to be accurate to  $\pm 0.3\%$ . These values were calculated from enthalpies measured by the drop method and a precision Bunsen ice calorimeter. For reference and comparison high temp. specific heats of seven other base-metal alloys were similarly determined; these are 80Ni-20Cr, 70Ni-15Cr-9Fe (three different samples), stainless steels types 317 and 446 and Monel 67%Ni, 30%Cu.

The effect of foliated structure on the properties of carbon steel M. A. Balter and N. M. Grinberg (Stal', 1961, (3), 271-274) Tests in foliated specimens confirmed the directional weakness in transverse shear. Notched and unnotched specimens were used and the occurrence of this type of fracture was shown to arise from defects in the metal and not from the manner of stressing. For parts subjected only to longitudinal strain it is quite satisfactory

Determination of the main shearing force parameters in the case of Roumanian steels undergoing longitudinal turning. III. The classes of constructional alloy steels: manganese steel, chromium steel, manganese-silicon steel, manganese-chromium steel and chromium-van-adium steel, STAS 873-53 G. Casler and A. Rener (Bull. Inst. Jasi, 1960, 5, (1-2), 353-354) IV. The classes of chromium steel and manganese chromium steel for cementation STAS 872-Raileanu and D V. The class of chromium-molybdenum steel for cementation and heat-treatment. 8TAS 792-49 V. Bausic and V. Belous (357-358) Employing a G. A. Levit-type dynamometer, the values of the parameters, of the classical equation for shearing forces in longitudinal turning, were determined for a series of Roumanian steels 15Mo-Crl2, 20Mo-Crl2, 25Mo-Crl1, 33Mo-Crl1, 41Mo-Crl1, and 25Mo-Crll, 33Mo-Crll, 41Mo-Crll, and 41Mo-Crl7. The results are shown on log-log

The effect of sulfur on the notch toughness of heat-treated steels J. M. Hodge, R. H. Frazier, and F. W. Boulger (Met. Treating, 1960-61, 11, Dec.-Jan., 14, 15) A summary paper. Transition temp, and impact tests results are presented as a function of sulphur content. It is concluded that for the steel investigated (0·3%C, 2·5%Ni, 0·8%Cr, 0·45%Mo) the Charpy V-notch impact resistance decreases increasing sulphur content, but the transition temp. was not substantially affected. Some data on directionality and homogenization treatment are also presented .-- A. H. M.

Minimum toughness requirements for high strength sheet steel J. A. Kies, H. Romine, H. L. Smith, and H. Bernstein (*Trans. ASME, J. Basic. Eng.*, 1961, **83D**, March, 1-9) These are indicated and the theoretical aspects are considered. In an appendix the method for estimating slow crack growth is added.-c.v.

investigation of spalling and crater formation by hypervelocity projectiles C. J. Maiden, H. P. Tardif, and J. Charest (Can. Min. Met. Bull., 1961, 54, Feb., 170-179) Results obtained experimentally of crater formation and spalling in metal to metal and metal to plastic impact are described, including hypervelocity penetration into targets with low acoustic velocities, penetration of cup-shaped projectiles into steel plates, and spalling of thin steel plates by hyper-

velocity spheres.—s. H.-s.

New standard proposals for the Erichsen cupping test on sheet and strip (Mitt. For-schungsge. Verarb., 1960, (19/20), 249-254) The proposed DIN standard, given the old number DIN 50101, Blatt 1 and 2, is reproduced and discussed

The instability of plastic flow of metals at very low temperatures. II Z. S. Basinski (Aust. J. Phys., 1960, 13, July, 354-358) Evidence is presented to show that the load drops observed in most metals at very low temp, arise from thermal rather than mechanical instability of the lattice. Measurements of the temp. rise are

The plastic resistance of crystals J. J. Gilman (Aust. J. Phys., 1960, 13, July, 327-346) Evidence is presented to show that crystals present a plastic resistance to dislocation motion which is almost independent of dislocation velocity except when velocities are very high. It is strongly influenced by temp. impurities and radiation damage. It is shown that the yield stresses and indentation hardnesses of many crystals can be correlated with their elastic moduli provided the crystal structure type is held constant. The temp. dependence of the plastic resistance is discussed and it is suggested that cores of dislocations in covalent crystals melt at a temp. which is about two-thirds of the melting temp.

The orientation dependence of work-harden ing in crystals of face-centred cubic metals L. M. Clarebrough and M. E. Hargreaves (Aust. J. Phys., 1960, 13, July, 316-326) The principal features of the observed orientation dependence of work-hardening can be accounted for in terms of the likelihood of formation of Somer-Cottrell sessile dislocations in two directions in the primary slip plane. This is deduced from the known variation of resolved shear stress with orientation for the possible secondary slip systems and metallographic observations of slip and deformation bands .- R.S.F.C.

Plastic deformations in the friction process I. D. Fainerman (Izvest. Akad. Nauk. Fiz. Khim. Anal., 1946, 16, (2), 7-12) Cold working of the surfaces of friction parts usually takes place beyond the limits of the temporary resistance of the material, and so before fric tion starts and 'initial' deformed layer has already formed. During the friction process plastically deformed layers of the substance appear at the friction surfaces, the substance having somehow lost its 'initial' properties. Plastic deformation had already been studied but the character of the process is insufficiently known. The author has investigated the problem by applying a new method, developed by him, for investigating friction. This is described and results obtained are given. -A.I.P.

New fatigue testing machine for wire rod H. Nakamura and T. Nishihara (Proc. 3rd Japan Congr. Test. Mat., 1960, 36–38; from Japan Mech. Elect. Eng., 1960, 7, Aug., 175) [In English] A description is given of a newly designed bending fatigue testing machine. The wire rod to be tested is rotated in a form of uniformly bent simple beam under arbitrarily set constant load and at variable speed. Some results obtained with this machine are shown and discussed .- c.F.C

Review of fatigue theories V. S. Ivanova Istalost' Metallov, Moscow, 1960, 3-18) (Ustalost' Metallov, Moscow, 1960, 3–18 Various theories are reviewed including early theories, strengthening, strengthening and weakening, resistance to break and fatigue, statistical, and dislocation theories (49 refs).

Some fundamental progress in fatigue C Massonnet (Rev. Tijd., 1960, 6, (4), 166-177). The author discusses initiation of fatigue failure, the influence of service conditions on the initiation of a crack, and propagation of the crack. Fundamental research in the author's laboratory on this subject is described and future programmes outlined (15 refs).—R.P.

The mechanism of fatigue (Can. Mines, Research and Special Projects Report 1960, 1961, 30-31) A correlation between the structural changes taking place in polycrystalline copper fatigue under torsional stress with the change of the cyclic stress-strain curve is attempted. It was found that persistent slip band and grain boundary markings occur upon completion of the work-hardening period. It was assumed that these were incipient or actual microcracks. Work-hardening period was less than 1% of fatigue life. At high strain amplitudes, considerable amplitudes, considerable grain distortion occurred at, or near, the end of work hardening. distortion This was shown by X-ray back-reflection patterns and cracking initiated at the boundaries. Distortion was progressively less as strain amplitude decreased. The effect of grain boundaries on fatigue processes is being studied; symmetrical and antisymmetrical bicrystals of Al are being fatigued under reversed plane bending at various stress levels. Direction of grain boundary is generally parallel to the direction of bending stress but some symmetrical bicrystals were grown with a boundary normal to the bending stress direction. effect of grain boundary on the development of slip markings, on the initiation and growth of cracks and fatigue endurance is being studied.

Fatigue fracture P. J. E. Forsyth and D. A. Ryder (Aircraft Eng., 1960, 32, April, 96–99) Some results derived from the microscopical examination of crack surfaces are examined and discussed; 17 illustrations are included which clearly show the presence of the classical 'tide marks'. If they are present it is usually possible to show the point at which the fatigue crack began and the limit to which it spread before final separation occurred; these marks are associated with low stress-long life failures rather than with high stress-short life and many service fatigue failures do not show these marks. Somewhat similar markings have been noted on tensile fractures but they are not so widespread, so evenly spaced, nor are they associated with long plateaux. Anomalous diffraction effects can be obtained by excessive 'stopping down' of the condenser iris and the absence of striations does not imply that the fracture did not occur by fatigue. sidered that this technique offers a simple and accurate means of measuring crack growth rate and extrapolation of the curve to zero crack length to determine the point of initiation should be reliable for less complex

Prediction of fatigue life A. M. Freudenthal (J. Appl. Phys., 1960, 31, Dec., 2196-2198) On the basis of the relation between the 'reliability-function' (probability of surviving beyond age N in cycles or t in time), and the 'risk' of failure (as a function of age), the physical interpretation of the latter can be used to extrapolate the former beyond the range of possible observation. It is shown that the asymptotic distribution of smallest values is compatible with the physical concept of (dynamic or static) fatigue, while the logarithmic-normal distribution is not .-

Strength of steels under repeated impulsive load T. Endo (Proc. 3rd Japan Congr. Test. Mat., 1960, 20–23; from Japan Sci. Rev. Mech. Elect. Eng., 1960, 7, Aug., 175) Materials with higher impulsive fatigue strength show higher rotary bending values independent of Charpy impact value. Carbon and alloy steels have

similar fatigue limits.-

Microfractography of fatigue fracture surface of metals. I. Observation of the fatigue fracture surface of some carbon steels by electron microscope A. Tokuda (Nippon Kinzoku, 1960, 24, (3), 171-175) [In Japanese] The fracture surfaces of steels containing 0.3%C were examined by a replica technique. The patterns, not resembling those of tensile or impact fractures, are classified as 'parallel', 'cliff', 'cleavage', 'caterpillar', and 'spine' types. Their features are correlated with stress parameters, sometimes quantitatively.-K.E.

Concerning the criteria of notch sensitivity of metal during cyclic loads I. A. Oding and S Gurevich (Ustalost' Metallov, Moscow, 47-61) The criterion of notch sensitivity is characteristic only of the tendency of the material to lower the stress peak under limiting cyclic loads and does not depend on the geometrical parameters of concentration stresses (the radius of notch curvature). The criterion given is suitable for calculations over a fairly wide range of concentration coefficients (20

Strength under repeated loads and resistance to brittle fracture S. I. Ratner (Ustalost' Metallov, Moscow, 1960, 34-46) Under cyclic loads both time and frequency are important factors. The part played by time depends on the special features of the material, amount of tension, and test conditions (14 refs).-

Certain data on physical relationships in the process of the failure of steel by fatigue E. M. Shevandin, R. E. Reshetnikova, L. M. Rubinshtein, and L. F. Khudozhnikova (Ustalost' Metallov, Moscow, 1960, 27–33) Brittle strength changes in a unique fashion with an increase in the number of preliminary-loading cycles. At first load increases, then decreases, with brittle strength reaching a maximum, and then after another maximum, settles to a steady level. Other data are discussed.—A.I.P

Influence of the melting procedure and alloying additions on the fatigue strength of steels, in particular spring steels M. Hempel (Draht, 1960, 11, Aug., 429-437) A general review, with reference to the literature. The metallurgical influences considered are melting technique, degree of purity, and deoxidation practice. The results of investigations on binary iron alloys were used to establish the effect of alloying additions, and the relationship of the fatigue strength to C, Si, S, and P content was exam-

ined (95 refs).

The influence of phosphating on the fatigue strength of steel H. Tauscher (Draht, 1960, 11, Aug., 442-448) Investigations on alloy steels K 30 Si-MnCr4 and K4ONiCrMo6 showed that the reduction in fatigue strength on phosphating was not more than 14%, i.e. no greater than the effect of Cd or Zn coating, and much less than the effect of hard Cr plating. The effect on fatigue strength is due mainly to the roughening of the surface taking place during

phosphating (17 refs).

Creep in steel J. D. Murray (Met. Treatment, 1960, 27, Nov., 461–467) The author describes the latest methods of design criteria under creep conditions with particular reference to the use of steel in pressure vessels. Metallurgical aspects of creep are then considered and these include the effects of interstitial elements, precipitation, and allotropic transformation. A brief outline is given of the principles applied in the development of new alloys and the author concludes with a discussion of the problem of evaluating creep data for tests of up to

lem of evaluating creep data for tests of up to 100000 h duration.—A.H.M.

Creep resistance strain gauges under static strain C. Rohrbach and N. Czaika (Eng. Digest, 1961, 22, Jan., 81–84; from Archiv für Technisches Messes, 1959, (287), 255–258; 1960, (289), 35–38; (290), 55–56) In electric resistance with the control of the control wire strain gauges, a grid of parallel wires connected in series is bonded to a thin paper base by an adhesive and the whole assembly is cemented to the surface under test. It has been accepted that the strain suffered by the wire is proportional at all times to that of the transmitting test surface despite the visco-elastic and non-linear properties of the non-metallic components of the assembly. In the present article this assumption is questioned. It is shown that strain gauges exhibit characteristic creep phenomena; these introduce noticeable error, especially with elevated temp. and extended times, and where high precision is required .- c. v.

Greep deformation: The analysis of creep in a thin rotating disc with a central circular hole B. V. Saroja (Air. Eng., 1960, 32, Feb., 34–36) Wahl's assumption that the radial creep strain rate,  $E_r = 0$  (using the Resca Criterion) and its associated flow rule have been eliminated and secondly, with regard to his analysis using the Mises Criterion and its associated flow rule, it has been found that the creep deformation curves (both inside and outside the dia.), and the creep strain curves fall very much below the scatter band. But, according to the present theory, a criterion very similar to the Mises has given deformations and strain which lie completely within the scatter band. It is concluded that the choice of  $\psi$  (r) greatly affects the distribution of stresses  $\sigma_r$  and  $\sigma_t$  and that dubiety is due to the arbitrary choice for the

correspond tensile loss in steel wire, particularly at slightly elevated temperatures W. Papsdorf and F. Schwier (F & G-Rundsc.,

1959, July, 183-198) A critical review of creep test results carried out to date is given, follow ed by the authors' own experiments and results. The effect of temp. decreases with prolonged testing and increased load. Changes in physical properties of wires subjected to creep tests are discussed (31 refs).—R.P.

The creep and rupture properties of 21/2% chromium 1% molybdenum quality steel
British Electrical and Allied Industries
Research Association (Electrical Research
Association, Techn. Rep. J/T172, 1959, pp.12)
A summary of British data (1% creep strain

and rupture) is given.—C.V.

Optimization in parametric constants for creep-rupture data by means of least squares S. S. Manson and A. Mendelson (NASA-M-3-10-59E, 1959, March, pp.34; from Nucl. Sci. Abs., 1959, 13, June 15, 1349) Examples are worked out.

Metallographic investigations on X8CrNiNb Metallographic investigations on Asternino 1613 after creep tests at 750° A. Schrader and A. Krisch (\*International Discussion on 'Long time behaviour of high temperature steels', Düsseldorf, 1960, Paper No.27, pp.16) The steel was an austenitic Cr-Ni product with 0·18% Mo which was stabilized by Nb and Ta. The behaviour under load at elevated temp. is followed, 33 illustrations showing the surface followed, 33 illustrations showing the surface cracks, grain boundaries, precipitations, and alterations in structure which have occurred after 29503 h at 750°. Concerning this test piece, there would appear to be considerably ewer pptd. crystals present; on the other hand, it is considered possible that this may be due to a coarsening of the individual particles during the prolonged testing period.-

Prediction of dynamic creep strength under combined stresses of static tension and repeated bending, using static creep data S. Taira and R. Koterazawa (Proc. 3rd Japan Congr. Test. Mat., 1960, 68-71; from Japan Sci. Rev. Mech. Elect. Eng., 1960, 7, Aug., 174) The prediction of creep under axial pulsating stress from static data has been worked out previously. Here creep under combined stresses is calculated from dynamic creep under axial pulsating

Correlation of creep data according to the quantistic theory of reaction speeds P. Brozzo (Met. Ital., 1960, 52, Dec., 865-882) [In Italian] A method is described of correlating creep data based on the quantistic theory of reaction speeds. The behaviour of metal in use at constant stress is expressed for any combination of tension  $\sigma$  of deformation  $\epsilon$ , of time te of the absolute temp. T by expressions given. The defects of previous approximations being pointed out.

Power plant: steels for high temperatures: metallographic investigation of a steel X8CrNi-Nb 1613 according to long-time creep tests at 750°C A. Schrader and A. Krisch (Arch. Eisenh., preprint. Paper from Internat. Discussion on long time performances of high-temperature steels, Düsseldorf, June 1960, pp.14) Structures and mechanical properties are surveyed with numerous tables and illustrations.

Greep and rupture properties of  $2\frac{1}{4}$  per cent Cr 1 per cent Mo steel (Eng. Materials Design, 1961, 4, Jan., 52-53) A data sheet.

Autofrettage of cylinders: prediction of pressure/external expansion curves and calculation of residual stresses G. J. Franklin and J. L. M. Morrison (IME Advance copy, 1961, pp.21) Studies on 2½%Ni-Cr-Mo steel used in the form of thin tubes in torsion were carried out and used to calculate the behaviour of thick cylinders by methods indicated. Actual full-scale investigations were made but the effect is small and the trials were inconclusive.—c.f.c.

The effect of gases on the hardness of rimmed and killed low-carbon steels B. S. Natapov and E. S. Fal'kevich (Izvest. VUZ Chern. Met., 1958, (11), 95–98) The effect of N<sub>2</sub>, H<sub>2</sub>, and O<sub>2</sub> on the hardness of low-C (0·07-0·1%) and Al-deoxidized steels is examined. Increase in the N<sub>2</sub> content, within reasonable limits, markedly increases the hardness of this deoxidized steel and there is an increase in hardness on strain ageing. It is emphasized that the min. amount of N should be allowed to enter these steels during production.  $H_2$  and  $O_2$  did not appear to show any effect, this observation being based on specimens taken from 12 heats.

Piping failures (Mech. World, 1961, 141, Jan., -18) Primary causes of pipe and tube failure, and the characteristics and nature of such faults are described for seven metallurgical classes of tubing.—s. H.-s.

Choice and ageing of steels for measuring instruments (Technica, 1960, 9, Nov. 4, 1417–1418) Properties and treatment of steels used for measuring instruments are discussed in relation to requirements to be met by the instrument .- R.P.

Methods of testing the artificial ageing of carbon steel F. Erdmann-Jesnitzer and Laschimke (Neue Hütte, 1961, 6, Jan., 44-52) After reviewing the literature, test methods are assessed and the influence exerted on the steel by the method of testing examined (23

A study of theories of fracture under combined stresses I. Cornet and R. C. Grassi (Trans. ASME, J. Basic Eng., 1961, 83D, March, 39-44) Materials ranging from relatively ductile nodular to brittle high-Si iron have been nodular to brittle high-si from have been investigated and the results obtained have been compared with those of other workers, 25 references being included. Microstructure and chemical analysis were not undertaken. In this work the term 'brittle' has been used to denote a material that can sustain without failure stresses of greater magnitude in com-pression than in tension and it is considered probable that the ultimate understanding and analysis of the physical phenomena of fracture of such brittle materials will be found in the application of the dislocation theory when this is properly understood.—c.v.

Brittle fracture (Can. Mines, Research and Special Projects Report 1960, 1961, 31–32) The nil ductility (NDT) temp. as determined by the and -105° for \$\frac{3}{4}\$ and \$1\frac{3}{2}\$ in thick HY80 high strength steel and plate respectively. The corresponding Charpy impact value was \$-90\$ ft/lb in both cases. Drop weight and Charpy tests have been carried out on \$1\frac{1}{4}\$ in thick, Nb-modified C-steel plate in the asrolled condition. The NDT temp, was \$-10^{\circ}\$ and \$1.5\$ lb transition temp. and the 15 lb transition temp. 40°. Similar tests on as-rolled Canadian grade 'B' plate of comparable strength gave lower values in both cases,  $-30^{\circ}$  and  $-40^{\circ}$  respectively. Further tests on these materials using the low-energy blow technique were made; these were pre-cracked at suitable temp. above the Charpy transition temp. and then tested over a range of temp. to study crack propagation resistance. The transition temp. were appreciably higher than those obtained in the standard Charpy tests but no direct correlation with the NDT temp, was found .-- c.

How can we prevent brittle fracture? H. H. Thomasson (Metalw. Bull., 1960, 23, (11), 38–39, 64) The problem of brittle fracture is much closer to solution. The claim that brittle fracture is essentially due to high residual stress, a notch and a temperature below that of the brittle transition range is critically examined.

Embrittlement of steel in contact with the liquid phase. III. Effect of several factors on embrittlement of solid metals in contact with liquid metals M. Nakajima (Tetsu-to-Hagane, 1961, 47, Feb., 134–138) The embrittlement of mild steel in contact with molten Cu or Cu–Snalloy or Sn in contact with Hg was examined. This type of embrittlement, fracturing by penetration of liquid, occurred at comparative low working speeds but was hardly noted at an impact working speed. Cold rolled steel, below the recrystallization temp. was less sensitive to embrittlement as rolling reduction increased; the cracks run along the strained ferrite-grain boundaries. Fine-grained Pb was not embrittled by Hg and the coarse grained variety showed no embrittlement in air. Fracture by liquid penetration occurred only at a definite stress value, this being demonstrated by constant tensile load of Sn in Hg.-c.v.

Notes on the brittleness of the steels AKI (Cr13) J. Koutský and J. Teindl (Hutn. Listy, 1961, 16, Feb., 129-135) [In Czech] Embrittlement of AKI steel at temp. below Ac, of three opening melts were studied. The authors discovered the characteristics of brittle states, analysed the processes of its cause and verified the importance of 'artificial ageing' and its association with embrittlement at operating temp. They found also a link between heattreatment and the minimum value of notch toughness on annealing to 450°C with a time of treatment of up to 1000 h.—R.S.F.C

Report of anomalous 'brittle failures of heavy steel forgings at elevated temperatures' A. J. Babecki, P. P. Puzak, and W. S. Pellini (ASME Publ. 59-MET-6, 1959, Jan., pp.12) Failures of four heavy Cr-Mo-V steel forgings serving as retaining rings for billet containers in Al extrusion at 800-950°F are described. Creep and grain boundary cracking occurred. Crack growth was followed and constant-load notch-tension tests on plate specimens at 900°F and drop-weight and Charpy V tests were also carried out.

Velocity behaviour of a growing crack E. N. Dulaney and W. F. Brace (J. Appl. Phys., 1960, 31, Dec., 2233-2236) An expression for the velocity behaviour of a growing crack in a plate of brittle material is obtained by a mathematical refinement of the Mott energy balance around a moving crack. Crack velocity c is given by  $C=V_T$  (1-Co/c), where  $V_T$  is terminal crack velocity, c is instantaneous halfcrack length, and Co is initial half-crack length. This predicts that velocity makes a hyperbolic asymtotic approach to terminal velocity. Growing cracks in large sheets of polymethyl methacrylate approach terminal velocity over three-quarters of their length as predicted by this theory but as though from an initial crack larger than the actual initiating crack. This is interpreted as due to energy losses at the very beginning of crack growth not included in the Mott energy balance.

A new look at the hydrogen embrittlement of cadmium coated high strength steels N. M. Geyer, G. W. Lawless, and B. Cohen (WADC-TR-58 481, 1958, Nov., pp.61; from Nucl. Sci. Abs., 1959, 13, June 15, 1353) A reliable test is developed. A plating process for coating steel without H<sub>2</sub> embrittlement is given and vacuum metallized coatings are also non-

embrittling Size effect in brittle fracture of notched Esteel plates in tension J. H. Ludley and D. C. Drucker (Trans. ASME, J. Appl. Mech., 1961, 28E, March, 137-139) It was suggested previously that the initiation of brittle fracture in ordinary structural steel plates is based on the assumption that a Griffith type of theory is not applicable. In the present communication, direct experimental evidence is presented to

support this contention,—c.v.

A crossed-cylinder wear machine and its use in the study of severe wear of brass on mild steel J. Halling (Wear, 1961, 4, Jan.-Feb., 22-31) A machine is described designed for use with a standard centre lathe, and may be employed in the following methods of testing: (1) the test specimen at rest in contact with the rotating cylinder; (2) the specimen being traversed along the axial direction of the rotating cylinder; (3) tests similar to (2) where a cutting tool prepares a freshly machined surface at a fixed time interval ahead of the wear test. Results for these methods of testing are given for the severe dry wear of a 60-40 brass rubbing on mild steel. For tests of type (1) the wear rate is initially constant and then increases owing to the effect of transformed metallic films. This type of behaviour is not noted for tests of type (2). In tests of type (3) it is observed that the wear rate increases as the time interval between cutting and testing decreases, and that marked intermittent seizure is also apparent.—s. H. - S.

Some practical examples regarding the endurance and stability of machine parts, and various motors G. Bourceau (Rev. M. Tijd., 1960, 6, (4), 193-208) Theoretical principles and experimental results are discussed regarding the endurance and stability of the crankshaft of a high-powered diesel engine, base plates for welded engine housings, and certain

parts of pressure vessels.—R.P.

Wear in rolling contact of white iron I.

Fukumoto (Nippon Kinzoku, 1960, 24, (4), 213–217) [In Japanese] Results are given for as-east and heat-treated specimens of 2-4% C white irons and 3% C Ni–Cr white iron in contact with spring steel. Wear increased with the number of rotations and with compressive stress. A deformed layer on the surface was a mixture of cementite and  $\alpha$ -iron. Blisters were found when the primary crystals of the iron were hard, or the %C high.—K.E.J.

The need for research on abraded and polished surfaces L. E. Samuels (Plating, 1961, 48, Jan., 46-49) The atomic structure of a surface, nucleation of growth, and dissolution are first considered. The second problem is the manner in which a surface departs from the ideal by contamination with an adsorbed gas, chemical nature of the change is well understood, the unknown is the physical form of the film. In considering plastically deformed layers produced by abrasion and polishing, it is found that there is an outermost portion where the distortions are specially severe and possibly of a different form from the remainder. This, and aspects associated with the cutting tools, are discussed. Surface flow and surface heating are briefly examined but in summary, stress is laid on the number of basic unsolved problems awaiting solution and that satisfactory progress in the finishing industry cannot be made until these are more fully studied.

The effect of the roughness of rolling bodies and rolling path surfaces on the internal clearance, with consideration of the durability of radial ball bearings N. G. Popinceanu and M. D. Gafiteanu (Bul. Inst. Jasi, 1960, 4, (1-2), 333-340) Measurements of ball-bearing dimensions have enabled the determination of a relationship between the roughness of unpolished rolling path surfaces and rolling bodies and the dia. The value of the roughness at 2% of the normal life-time of the ball bearings and the operational roughness were further determined, leading to the conclusion that the effect of the roughness of the rolling bodies is negligible, so that only the roughness of the rolling path surface needs to be taken into account in calculations. The relationship established enabled evaluation of the durability of radial rolling bodies as a function of internal clearance to be made and the results agreed well with experimental data.

Non-destructive testing of metal components used in transport E.G. Ramachandran (TISCO, 1961, 8, Jan., 57-65) Radiography, ultrasonics, magnetic, and electrical testing are briefly discussed and compared .- c. v.

Non-destructive testing in Great Britain (Nondestr. Test., 1960, 18, Nov.-Dec., 411, 412) The article lists the members of the British National Committee for Non-destructive Testing and makes reference to the Institution of Engineering Inspection, the Non-destructive Testing Group of the Inst. of Physics, and other bodies. Closer liaison and integration of effort between these bodies is suggested .- A.H.M.

Determination of tensile and compressive stresses in steel using magnetic measuring methods H. Habermann (VDIZ, 1961, 103, Jan. 21, 111) An abstract of a thesis, in which the possibility is examined of determining by the magnetic behaviour the uniaxial stresses in structural and machine steels. The method described in the original thesis is suitable for the determination of mechanical stresses in ferromagnetic materials.

Observation of domains in iron whiskers under high fields C. A. Fowler jun., E. M. Fryer, and D. Treves (J. Appl. Phys., 1960, 31, Dec., 2267-2272) An improved instrument utilizing the longitudinal Kerr magneto-optic effect is used to observe the magnetic domain development in iron whiskers undergoing a magnetization cycle. It is found that domains persist at the tip of the whisker even under conditions for which the crystal is usually assumed to be saturated. Under applied fields of a few thousand Oe these persistent domains at the tip, in all of the specimens observed, are magnetized perpendicular to the axis of the whisker and in the same sense around its lateral faces. It is proposed that these domains are caused by the high fields localized near the sharp corners and edges of the crystal.-C.F.C.

Magnetic properties after remelting and in the compact state of irons of high purity produced by fusion electrolysis C. Goillot and S. Ziolhiewicz (Compt. Rend., 1961, 252, Feb. 6, 879–881) The preparation of sections for the study of magnetic properties is briefly described and their treatment indicated .-

Magnetism of the iron particles as revealed by electron diffraction S. Yamaguchi (Indian J. Phys., 1960, **34**, Nov., 535-537).

Study on OP magnet (3rd rep.). Influence of phosphates and arsenates of the element of group II on OP magnet H. Nakamura, N. Kawai, and H. Yoshida (J. Japan Soc. Powder Met., 1959, 6, Aug., 155–159).

Domain configurations about nonmagnetic particles in iron W. D. Nix and R. A. Huggins (*Phys. Rev.*, 1961, **121**, Feb. 15, 1038-1042).

On ferromagnetism in the Mn Al-Fe system I. Tsuboya (Met. Phys., 1960, 6, Nov., 263) [In Japanese] [No summary].

Studies on some magnetic properties of permanent magnets S. Miyata and N. Makino (Nippin Kinzoku, 1960, 24, (3), 139-142) [In Japanese] Data are given for the uniformity of magnetic flux and its temp. variation, magnetic stability, leakage factor in magnetic circuits, etc., in commercial magnets and MT allov.—K.E.J.

On the effect of isothermal magnetic annealing on the magnetization and magnetostriction at high and room temperatures in a Fe<sub>3</sub>Cr superlattice alloy H. Masumoto, H. Saito, and M. Takahashi (*Nippon Kinzoku*, 1960, **24**, July, 465–469) [In Japanese].

Magnetic latching crossbar switches: a new development in magnetic properties of tool steel F. A. Zupa (Bell Tech. J., 1960, 39, Sept., 1351– 1378) A magnetic latching function in crossbar switch hold magnets is obtained by using a specially-designed magnet core of high-C tool steel. This fabricated core is given a hardening heat-treating cycle designed to impart a special degree of physical hardness with optimum magnetic properties enabling the pulse operation and magnetic latching to function efficiently under a wide range of contact springloads. The heat-treatment, the loads, and the operating power are described.—c.v.

Effect of neutron bombardment on magnetic properties of very high permeability iron G. Biorci, A. Ferro, and G. Montalenti (J. Appl. Phys., 1960, **31**, Nov., 2046–2047) Rings of iron with permeability of about 150000 after neutron bombardment (10<sup>18</sup>nyt), show lower permeability and higher coercive force. This effect can be interpreted as due to large defects giving long-range internal stresses, or as due to anisotropic defects interacting with the magnetization vector at each point of the specimen.—c.f.c.

Inspection—the eddy current non-destructive testing of metals S. S. Goldberg (Metallurgist, 1961, 1, (7), Jan., 243-245) The use, limitations, and discrimination of eddy current techniques are discussed, with methods of testing, including a reference to testing of magnetic materials.—s. H.-s.

Specifications and standards for eddy current: flaw detection in tubing R. Hochschild (Non-destr. Test., 1960, 18, Nov.-Dec., 403-407) The author starts by considering the initial adjustments of the test instrument and factor affecting its sensitivity. He then considers performance standards and lists the artificial defects normally used in reaching these standards. Calibration standards are then considered and the article is concluded by discussing the correlation between results obtained from natural defects with those from artificial standards.-A.H.M.

The susceptibility and the electrical resistance of homogeneous and nonhomogeneous copperiron alloys C. Berghout (Z. Metallk., 1961, 52, March, 179–186) The magnetic susceptibility and electrical resistance of a series of homogeneous and nonhomogeneous Cu-Fe alloys, with a Fe content of a few percent, were measured. It was found that an unexpected temporary ferromagnetic interaction between the Fe atoms took place in the course of the first stage of precipitation. The susceptibility and electrical resistance of these partly pre-cipitated alloys were affected in a marked degree by cold working, the magnetic suscepti-bility itself below the Curie temp. of 200°K became anisotropic when the alloys underwent plastic deformation.-M.L.

Ultrasonics and its applications. Magneto-striction generator J. M. Serra Martínez (Rev.

1961, 15, Jan.-Feb., 1-13) [In Spanish] The various methods of generating ultrasonic waves are considered and the design and construction of a magnetostriction genermens and operating in the range 10-50 ke is discussed. Full constructional details are provided. Various applications of ultrasonics are

reviewed (46 refs).-

Ultrasonic pulse-echo techniques for evaluating thickness, bonding and corrosion D. Erdman (Nondestr. Test., 1960, 18, Nov.—Dec. 408–410) A recently developed pulse echo apparatus is described in which the traditional cathode ray tube has been replaced by a direct reading meter. Examples are given of the application of the instrument to corroded gas pipes. It is claimed that the apparatus is capable of measuring thickness of 0.050in with 1%accuracy .- A. H. M.

A new method for the quality control of cast iron by ultrasonic testing A. Lehtinen (IGK Kongress Vorträge, 27th International Foundry Congress, Zürich, 1960, 79-83) [In German] In the method described, ultrasonic testing can be extended to hot, or even liquid cast iron. A cooled steel rod, to the upper end of which a transducer crystal is attached, is used to transmit ultrasonic impulses into the cast iron. In this way the change of sound velocity v. temp., can be followed from the liquid condition to

Ultrasonic testing of heavy steel castings W. Rauterkus (Giesserei, 1960, 47, Sept. 8, 475-486) The difficulties of assessing steel castings by ultrasonic methods compared with forged or rolled steel are pointed out, and measures to be adopted to obtain an accurate interpretation of readings of the interior of heavy steel

castings are discussed. On the problem of the ultrasonic inspection of big forgings as a criterion of their operational applicability V. Koblovský (Hutn. Listy, 1961, 16, March, 174–185) In the light of an actual example the limitations of the method and the best way of operating it are discussed.

Automatic ultrasonic weld-testing J. Draut-krämer and H. Drautkrämer (Metalw. Prod., 1961, 105, March 1, 62-63) An automatic ultrasonic apparatus for testing welds at speeds of approx. 6 ft/s is described, with details of its set-up and use in detecting and marking flaws in welded pipe seams at welding speed.

Automatic ultrasonic testing of welds (SS News, 1961, Jan., 12-15) Speed of production in the automatic welding of longitudinal seams in large-dia. pipes (20in) is such that normal methods are too slow to carry out a 100% inspection. It is however claimed that weld defects can be detected accurately by ultrasonic testing by the use of three probes: A and B search the weld for longitudinal flaws (cracks, incomplete penetration, etc.), while C scans for transverse cracks, piping, and inclusions. Piping can be found by any of the probes. Flaw echoes occurring within the gate can give visual or audible warning or can mark the position by a paint spray gun while a pen-and-ink recorder can register the position and the height of the flaw echo.—c.v.

Ultrasonic section recorder (SS News, 1961, Jan., 6-11) Normally the examination of a large specimen (forging, casting crankshaft, etc.), involves an extensive listing of results but a photographic recording is now proposed. The mechanism of this, the positioning, and movement of the probes and the interpretation of the results are discussed in some detail.

What size drive rod between vibrator and test piece? D. Cerasuolo (*Prod. Eng.*, 1961, **32**, March, 82-83) In vibration testing it is not always possible to attach the exciter directly to the piece of equipment being tested and the drive rod has to transmit the vibrations. Examples are provided and nomographs are given; these enable the problem to be rapidly solved.-c.v.

The immersed ultrasonic inspection of metal plate R. M. McClung (ORNL-2650, 1959, April 6, pp.22; from Nucl. Sci. Abs., 1959, 13, June 15, 1351) Plates down to lin can be measured. Defects are shown.

Relationship existing between the size and position of geometric defects and the results of ultrasonic testing M. Ferrero and P. Ravizza (Met. Ital., 1960, **52**, Dec., 913-924) [In Italian] This study describes and reports the results of experiments on one of the main prob-

lems of ultrasonic testing

Ultrasonic quality inspection of nodular iron castings P. Réti (Gép. 1960, 12, (6), 217-222; from Hungarian Technical Abstracts, 1961, 13, (1), 11) A process based on the damping of ultrasonic frequencies has been developed for the rapid and unequivocal noncorrosive of crankshafts produced from nodular cast iron with the object of determining the nodular nature of the iron castings. The process is based on multiple echo-type thickness measurmethods .- R.S.F.C.

Ultrasonic-resonance method of thickness measurement M. V. James (Trans. Soc. Instr. Techn., 1961, 13, March, 49-57) The underlying theory is discussed and two practical instruments using this technique are described due consideration being given to the design of the transducer and factors that will affect measurements. Surface condition is most important since corrosion, pitting and scale, may prevent transmission of energy from the transducer; tapered materials also reduce strength of reflected waves. Various other factors are also discussed .- c.v.

Can flakes be detected as such in forgings with the aid of the pulse echo method? G. Beekmann (Neue Hütte, 1961, 6, Feb., 99-106) [In German] The difficulties encountered in ultrasonic testing are investigated, also the reflectograms diverging from the standard case and their causes. The influence of the proximity field during flake detection is discussed. real value of expertise is assessed and substitute error sizes are given.-R.S.F.C.

X-Ray measurement of grain size B. E. Warren (J. Appl. Phys., 1960, 31, Dec., 2237–2239) When the number of crystals contributing to a powder pattern peak is small, changes in the position and orientation of the sample produce statistical variations in the measured integrated intensity. The statistics are those of Poisson distribution, and the effect can be utilized in a very simple way for an absolute determination of grain size. Only relative intensity measurements are required. Grain sizes down to about 1-2  $\mu$  can be measured by this method. There is an interesting possibility of varying the experimental conditions in such a way as to distinguish between the sizes of grains and subgrains .- c.F.c.

X-Ray diffraction measures stress even in hard steel (SAE J., 1961, Jan., 72–76) An experimental technique is described employing a two-exposure method together with the use of diffractometers. It is claimed that even in hard steels the method is capable of measuring internal stresses to an absolute accuracy of 50000-10000 lb/in<sup>2</sup> and a reliable accuracy of 4000-5000 lb/in2.-A.H.M.

High temperature furnaces for X-ray diffractometers W. J. Campbell, S. Stecura, and C. Grain (US Bur. Mines, RI 5738, 1961, pp.30)

Backscatter method of wall-thickness measurement L. E. Taylor (Trans. Soc. Instr. Techn., 1961, 13, March, 58-62) Despite the fact that the method of measuring tube and plate wall thickness by the measurement of backscattered gamma radiation has been known for some time, as yet few commercial instruments are available. The principle is discussed and the instrument is described, the uses, advantages, and disadvantages being summarized. At present these measurements are restricted to the static state but the application to materials in motion is envisaged although a very close tolerance in distance will have to be maintained between the source/ detector combination and the material under examination. Nevertheless work in this direction is progressing.—c.v.

The use of radioisotopes in metallurgy F. Vander Linden (ATB Mét., 1960, 4, (2), 51-57) Several applications are described as examples, including measurement of refractory wear automatic control of the movement of material in a furnace, and measurement of the charge level in a blast-furnace

Engineering applications of isotopes (Eng.Materials Design, 1961, 4, Jan., 35–37) Some of the papers on radioactive tracer applications presented at a conference held in Copenhagen on the Uses of Radiosiotopes in the Physical Sciences and Industry are reviewed. They deal with research on lubrication and wear, flow patterns, and leak detection, and storage capacity of batteries.

Penetration of fast neutrons through lead and iron D. L. Brøder, A. A. Kutuzov, V. V. Levin, V. V. Orlov, and A. V. Turusova (Kernenergie, V. V. Orlov, and A. V. Turusova (Kernergie, 1960, 3, July, 656-662) A theoretical method for calculating the penetrating power of neutrons is presented. Experimental results for iron and lead shields are found to agree well with calculated values (14 refs).-R.P.

471-491) Thermal dilatometric curves, temp., spectra, and endoelectrical diagrams of high-purity Fe (99.98%+0.009%O) and Fe oxides were studied and certain conclusions reached concerning internal changes within these materials in the course of heating. The most important changes from the practical viewpoint are those occurring in the Sirovich point domain, 363–385°C, and at 551°C.—M.L.

Effect of arc strikes (Can. Mines, Research and Special Projects Report for 1960, 1961, 19-20) A specially-designed equipment enabled line arc strikes to be produced on steel samples; these were compared with spot arc strikes previously investigated. A combination of these two strikes was comparable in crackinitiating potential with the brittle weld de-posit used on the conventional drop-weight test. This latter test was carried out to determine the effects of strikes and was as severe for steels with moderately high transition temp. as for a steel of low transition temp. With a single spot are strike as crack starter in the drop spot are strike as crack starter in the drop weight test, the transition temp. were  $-25^{\circ}$  and  $-32^{\circ}$  for two steels which gave nilductility transition temp. of  $5^{\circ}$  and  $-22^{\circ}$  respectively in the conventional test. The arc strikes still behaved as potent crack initiators although less severe than the brittle weld deposit. Previous work had shown that are strikes could be repaired by superimposing weld metal; to determine the cause of this, the effect of tempering the arc strikes was tried. Test samples treated for 1 h at 650°, showed that brittle fractures were not propagated even down to  $-60^{\circ}$ ; without the tempering, transition was found at  $-32^{\circ}$ . The improvement was found despite small cracks in the heat-affected zone of the arc strike but this zone was made more notch-tough than the base metal by the tempering.-

Analytical procedures for evaluating hightemperature failures W. R. Foley (Metals Eng. Quart., 1961, 1, Feb., 90-101) These methods are used in the examination of elevated-temp. failures in power boilers but the procedures are those commonly employed in metallurgical laboratories; they include visual and macroscopic examination, metallographic procedures analysis of scale and deposits utilizing spectrographic, X-ray, and wet-chemical techniques and mechanical tests. Examples of various failures are given and discussed.—c.v.

Mechanical properties of martensitic 13% nickel steel at liquid air temperature H. Schumann (Neue Hütte, 1961, 6, Feb., 92–98) [In German] Strength and notch-impact strength values of X8Ni13 in the rolling state and after different heat-treatments are noted. The processes taking place during annealing are also described.

The thermal shock resistance of grey- and spheroidal cast-irons J. Koritta and K. Löbl (Slévárenství, 1961, 9, (1), 6-7) [In Czech] The formation of cracks as a result of thermal shocks was studied in both types of cast-irons in the range 700-800°C, the test pieces being in the range 700-800 C, the test pieces being cooled from the high temp. by jets of water. The spheroidal east irons were found to be superior to the grey irons in all cases. Metallurgical aspects of the results are discussed.

Pulse method for the measurement of thermal diffusivity of metals E. L. Woisard (J. Applied Phys., 1961, 32, Jan., 40-45) Reporting an experiment in which data are obtained from thermocouples recording the progress of heat pulses along an infinite bar. The calculation of the thermal diffusivity is quite simple, the data are taken in less than 1 min, and only

relative temp. measurement is needed. The method was tested on commercial 'A' Ni, giving a result in excellent agreement with previous values. Results are reported for four new steels developed by the Bethlehem Steel

Company.-C.F.

Resistance materials for elevated temperatures, their properties and applications B. Edwin (Elektrowarme, 1961, 19, March, 102–110) The properties of a series of resistance materials are surveyed, especially Fe-Cr-Al and Cr-Ni alloys. Their chemical properties, as far as oxidation and oxide film formation, service life, resistance to high temp., corrosion. and the action of inert gases are concerned, and their physical characteristics, in so far as electrical resistance and temp. limits are con-cerned, were evaluated. It was determined that the arrangement of furnace heating elements is of considerable importance and special attention was given to the various factors involved. A Mo-Si<sub>2</sub> alloy prepared by powder metallurgical methods was also studied, determining its upper thermal useful limit at 1700°C.—м.1

Influence of induced internal stresses on the endurance limit O. Puchner (Czech. Heavy Ind., 1961, 1, Jan., 5-11) A review, describing increase of strength by local heating, test results of joints without direct acting load and test results of directly loaded corner joints, with a brief summary and bibliography.—s. H.-s.

Experimental thermal stress analysis in structural parts using photoelasticity and similarity laws G. U. Oppel (Europ. Masch. Markt., 1961, 11, March, 13e-18e) Introductory discussion of thermal stress analysis by photoelasticity is followed by detailed information about similarity laws used for evaluating thermal stresses as measured in models, where time scale and stress scale are considered. The application of photoelasticity laws is also considered .-- s. H.-s.

Calorimetric measurements on iron-carbon alloys E. Schürmann and K. Hagedorn (Giesserei Techn.-Wiss. Beih., 1960, (30), Oct., 1639-1646) An account of the wide variation in the reported values of the heat of formation of cementite; measurements on white and grey Fe–C alloys gave a result of  $+5400\pm150$  cal/mol Fe<sub>3</sub>C. Measurements were also carried out on the partial heat of solution of graphite and Fe<sub>3</sub>C, the integral heat of mixing of the system iron-iron carbide, the heat of fusion of cementite, and the heat capacity of molten Fe-C

alloys (30 refs).

The influence of various impurities and alloying elements on the viscosity behaviour of high carbon iron, with reference to flow properties, surface tension and mould-filling capacity A. Königer (Giesserei Techn.-Wiss. Beih., 1960, 28, April, 1557-1562) The effects of the interaction of individual alloying elements in multiphase systems in viscosity were examined, using a rotational viscometer. Particular attention was paid to the influence of S and P on the viscosity of alloys with high and low Si contents. Further tests were carried out with casting spirals (12 refs).

Method of simultaneous measurement of the coefficients of autodiffusion or heterodiffusion in bulk and at the joints of grains P. Guiraldena M. Ancouturier, and P. Lacombe (Compt. Rend., 1961, 252, Feb. 27, 1317-1319) A method is proposed which is claimed to offer the advantages of measuring on the same sample the relative depths of mass and intergranular diffusion, the correlation between the techniques of counting both on the autoradiography, and reproducibility of results, even for activities of very different origin.

Influence of alpha-forming elements on the diffusion of copper in gamma iron F. Sircu (Rev. Mét. Mém. Sci., 1960, 57, Nov., 879-887) It is shown that diffusion of molten Cu in y-iron is intergranular, the liquid wetting the grain boundaries. The presence in the Cu of  $\alpha$ -forming elements such as Cr, Sn, and Sb intergranular penetration; this is favoured by the presence of Al.

Measurement of the self-diffusion in a-iron and of the diffusion of cobalt-60 in α-iron W. Lange, A. Hässner, and E. Dahn (Neue Hütte, 1961, 6, Jan., 33-44) The self-diffusion of α-iron was measured by the thin layer and the absorption methods, and the diffusion of <sup>60</sup>Co in  $\alpha$ -iron was measured by the thin layer method, as a function of temp.  $^{59}{\rm Fe}$  and  $^{60}{\rm Co}$  were used as radioactive tracers, and were electrolytically deposited on Armeo iron specimens. The results are reported, and discussed in relation to the literature (33 refs).

On the surface tension at austenite grain boundaries K. Mazanec and E. Kamenska (Hutn. Listy, 1961, 16, (1), 41-49) [In Czech] The surface tension of austenite obtained from mild steel was found to be about 800 dyne/cm<sup>2</sup> at 1100°C. The surface tension at the austenite-ferrite boundaries was also studied at temp. at which the austenite decomposes isothermally.—P.F.

The surface tension of Fe-Mn and Fe-8 alloys Wan Zsin-Tan (Bergakademie, 1961, 13, Feb., 106) Alloys of Fe-0.001%O<sub>2</sub>, 0.001-0.002%C, 0.002%Si, <0.002%N<sub>2</sub>, traces of Cu, Si, and Ni with electrolytic Mn-0.05%S, 0.06%C, and chemically pure S were studied for their surface tension, in the form of a molten sessile drop. The results are summarized in diagrams which indicate the effect of Mn and S respectively on the surface tension.

Gases in ferroalloys B. Marinček and R. Limpach (IGK Kongress Vorträge, 27th International Foundry Congress, Zürich, 1960, 153–165) [In German] The determination of gases in ferroalloys is described in vacuum fusion equipment working at up to 2000°C, with equipment for recording gas evolution graphs. The results are discussed.

The diffusion and solubility of hydrogen in etals W. Eichenauer (Rev. Mét. Mém. Sci., metals W. Eichenauer (*Rev. Mét. Mém. Sci.*, 1960, **57**, Dec., 943–948) Diffusion and solubility coefficients were determined by measuring the rate of degassing of metals, including  $\alpha$ -iron, which was studied in the temp. range 200-774°C. The results are reported, and the mechanism of H<sub>2</sub> diffusion discussed. In the case of Ni, the coefficients were also measured for deuterium (25 refs).

Hydrogen in iron M. Ferrero and G. Timo (Met. Ital., 1960, 52, Dec., 779-785) [In Italian] During studies on the causes of the inclusion of gases in steels, research into H2 content of pig-iron was carried out. After describing the method used the results are given and analysed in order to establish the laws of H, diffusion at various temp.

Behaviour of hydrogen in cast steel P. Bastien (IGK Kongress Vorträge, 27th International Foundry Congress, Zürich, 1960, 47-57) [In French] Particular attention is paid to influence of H2 on steel castings. The method used to determine H, is described, i.e. vacuum fusion equipment incorporating a Pd filter—and this is followed by a review of the causes of the introduction of H<sub>2</sub> into steel, defects due to its presence, and methods of lowering the H<sub>2</sub> content (17 refs)

Contribution on the permeability to hydrogen, its adsorption and desorption on electrolytic nickel, at room temperature, with or without deformation F. Erdmann-Jesnitzer (Bergakademie, 1961, **13**, (1), 8–16) The behaviour of  $H_2$  in electrolytic Ni (softened by annealing as ll as cold formed) was studied in comparison with α-Fe. Both forms of Ni are impermeable at room temp, and the adsorption as well as desorption of H, were found to be much higher than in the case of  $\alpha$ -Fe, the amount of adsorbed  $H_2$  being a function of the surface area, which is explained by the slight diffusion rate of H2 through Ni at room temp., thus being present in a very thin layer, at the surface (17 refs).—M.L.

An X-ray investigation of the effects of hydrogen in iron A. S. Tetelman, C. N. J. Wagner, and W. D. Robertson (Acta Met. 1961, 9, March, 205-215) X-ray line broadening resulting from cathodic charging of hydrogen into annealed and cold-worked pure iron was investigated. At room temp. it resulted in a broadening of all reflections, and Fourier analysis showed that the broadening was caused both by distortion and the presence of small, anisotropic domains. The Fourier coefficients, half-widths, particle sizes, strain, and recovery kinetics were found to be identical for iron that had been charged with hydrogen and for iron strained 5% in tension; the apparent activation energy for recovery of line broadening, following either cathodic charging or a tensile strain of 5%, is  $42.0\pm$ 5 kcal/mole in the temp. range 400– $500^{\circ}$ C. No significant change in lattice parameter was observed as a consequence of cathodic charging. All evidence indicates that effect of H<sub>2</sub> on X-ray diffraction characteristics is best interpreted in terms of plastic deformation, with no evidence to substantiate the recent proposal that H occupies tetrahedral interstitual positions in the iron lattice.—s. H.-s.

Hydrogen in carbide in steel T. G. O. Berg (Amer. Ceram. Soc. Bull., 1961, 40, Feb., 78–80) Indirect evidence suggests that  $\epsilon$ -Fe<sub>2</sub>C is a  ${
m H_2}$ -rich phase and this is confirmed by direct analysis. Removal of  ${
m H_2}$  from this carbide requires its decomposition which occurs rapidly at high temp. but slowly at lower temp. The occurrence of fish scaling is associated with retained H<sub>2</sub> in the Fe<sub>2</sub>C, and its prevention is discussed. This is achieved by the tion is discussed. This is achieved by the formation of a stable  $H_2$ -bearing compound (TiC or TiN) which replaces  $\epsilon$ -Fe<sub>2</sub>C and retains the  $H_2$  permanently, by conversion of retained austenite into ferrite and cementite which can be attained by cold work converting austenite into ferrite and e-Fe2C followed by heating  $(\epsilon - Fe_2C \rightarrow Fe_3C)$  and by the prevention of the formation or retained austenite which is the source of ε-Fe<sub>2</sub>C, this being attained by composition control (low N2 values or by binding N<sub>2</sub> with Ti).—c.v.

Comment and discussion on Owe Berg's paper, 'Hydrogen in carbide in steel' G. P. K. Chu (Amer. Ceram. Soc. Bull., 1961, 40, Feb., 80-81) The forms in which H<sub>2</sub> can exist in a metal are reviewed but the Berg definition of 'retained H<sub>2</sub>' is regarded as not being explicit. The fish scaling is the end result of the 'evolved or diffusible  $H_2$ ' after enamel firing in an indicated temp. range. If the  $H_2$  is not diffusible ible, or only slightly so at this or a lower temp., fish scaling will not occur and the views of Petzold and Kotyk on Ti-steels, are compared. These views appear to suggest that although H<sub>2</sub> may be dissolved it is not detrimental long as it is not subsequently liberated. The necessity for further research in this direction is apparent.—c.v.

The solubility of nitrogen in the liquid alloys ferro-vanadium and ferro-titanium and the equilibrium in the reaction  $xTi\!+\!N\!=\!Ti_{f x}\!N(oldsymbol{\delta})$ equilibrium in the reaction  $xTi+N=Ti_xN(\delta)$  M. M. Rao and N. Parlee ( $Rev. M\acute{e}t. M\acute{e}m. Sci.$ , 1961, 58, Jan., 52–60) Gas absorption at various partial pressures were measured using a Sieverts technique. The conformity to Sieverts law for both ferro-alloys was examined (10%V at 1687°C and 10%V at 1750°C, and the Ti alloys at 1600°C). Activity data and Fe-Ti-N phase diagram data were also reported. reported.

How to counteract the effect of nitrogen on steel quality Y. G. Gurevich (Izv. VUZ Chern. Met., 1958, (10), 31-35) Observations have been made on fractures occurring in quenched specimens which show light areas of peculiar crystal structure. This is done by creating conditions of crystallization which do not allow of the formation of AlN. This is achieved by the addition of 0.05-0.1%Ti to the heat in the furnace, but the addition of higher concn. may result in new defects due to Ti nitride. The underlying theory of this addition is based on the temp. dependence of the standard free energy of formation of nitrides and equilibria of the N and Ti and N and Al contents in steel at 1470 and 1600°.—c.v.

Effect of tin on the mechanical properties of pearlitic nodular iron J, C. Prytherch and G. N. J. Gilbert (Found. Trade J., 1961, 110, Feb. 16, 197-206) Small conen. of Sn in nodular cast iron suppress the formation of free ferrite without producing massive cementite. Sn also increases the perfection of the graphite nodules while the addition of this metal progressively increases the hardness and proof stress of irons at all silicon levels; however, the effect of Sn on tensile strength is related to the ductile-to-brittle transition temp, and the toughness developed under impact conditions. Mechanical data shows that high Si and Sn together may under certain circumstances be undesirable. Normalizing resulted in toughness and an iron embrittled by Sn in the as-cast condition may have a normal tensile strength after normalizing. The beneficial effect of

normalizing is probably associated with homogenization of the structure, this occurring during the heat treatment .- C.B.

The influence of additions of austenite-forming elements on the properties of Kh28 steel A. A. Babakov and T. A. Khadan (Stal'), 1961, (3), 276-279) Not less than 4 % Ni greatly improves ductility, corrosion-resistance, and weldability, Kh28N4 is recommended as a substitute for austenitic Kh23N12 and Kh23N18 for high temp, use under moderate load and for chemical plant operating in corrosive atmospheres.

The effect of niobium on the properties of 18 Chromium 12 Nickel austenite stainless steels R. Nakagawa and Y. Otoguro (Trans. Res. Inst. Met., 1960, 2, (2), 63-68) [In English] Ageing hardness was higher and ageing time longer with decreasing temp. Precipitates found were NbC and  $\mathrm{Cr}_{23}\mathrm{C}_6$ , the amount of this latter being greatest in ageing at 650°C and becoming less with a rise in ageing temp. or with increase in Nb content.  $\sigma$ -phase was not observed in Nb specimens aged for 500 h at 560°C. High temp, deformation resistance depended only on the Nb content in the dissolved matrix and the high temp impact value decreased with decreasing Nb content; Nb had little effect on high temp. tensile strength within the range studied but creep rupture strength by carbide precipitation was marked at 650° but did not occur above 700°.—c. v

The influence of additions of nickel to The influence of additions of nickel to austenitic manganese steel G. Violi (Fond. Ital., 1961, 10, (1), 5–10) [In Italian] The effects are given in detail and illustrated by micrographs. The author recommends the study of the effect of additions of  $N_2$  to austenitic Mn steel.

Applications of uranium in ferrous metallurgy (Can. Mines Research and Special Projects Report 1960, 1961, 52—54) Ingots of medium U-bearing steels were produced in a 500 lb electric furnace and the forging and rolling characteristics evaluated. Segregation in the ingots was studied by chemical analysis and autoradiographic surveys. The influence of vacuum stream degassing on segregation was studied. Optical and electron microscope, X-ray diffraction, microradiography, and carbon extraction techniques were also used and these enabled the changes to be followed that were brought about by deoxidation, rolling, and forging practices and to study the more complex steels containing other alloying elements. Mechanical tests on plain carbon U bearing steels show that the fatigue-ultimate strength ratio is improved by small additions U. The normal relationship between ductility (elongation and area reduction) and tensile strength is followed up to 0.3%U but impact values fall rapidly when U exceeds 0·15% in steel containing 0·4%C but considerably less at a C 0·1%C level. With this C conen. the drop in impact becomes noticeable with as little as 0.05% U. U had a beneficial on high-temp, creep-rupture properties of a 0.4%C steel; these are equal to, or may be better than those obtained with C-Cr-Mo steel This finding is being further investigated. Critical points and tempering characteristics show no major change in heat-treatment for steels up to 0.7% U and in the deoxidation of steel U modifies the sulphide conferring greater ductility; however this does not appear to be economically advantageous. Further tests are being carried out.—c.v.

The production, advantages and uses of some types of semi-killed steels E. Hečko, J. Teindl, and B. Otta (Hutník, 1961, 11, (1), 11–15) [In Czech] The tendency to replace killed by semikilled steels for economic reasons, and to replace effervescent by semi-killed steels for quality reasons, are discussed with reference to ecent trends in the technology of production of semi-killed steels in the main industrial countries. In Czechoslovakia semi-killed steel is in use, in the manufacture of welding electrodes, concrete reinforcements, and certain types of tinplate .--P.F.

Development of low alloy steel compositions suitable for high strength steel castings H. Larson and F. B. Herlihy (Trans. AFS, 1959, 67, 718-731) The use of high-purity charge

materials improve ductility at high strength levels; homogenization at 2280°F also improved this quality at the ultra-high strength level but not at a tensile strength of 180000 psi. Alloying elements should only be added to the extent necessary to obtain adequate hardenability. If present in excess, there is a tendency to promote austenite retention. Izod impact strength varies with tempering temp. giving a max. value at 400°F and min. at 700°F. For a given tensile strength specification, C-content should be adjusted to avoid tempering between 500-850°C --- C. V

On the mechanism of transport of hydrogen across a solution-metal interface R. J. Barton (Tech. Proc. Amer. Electroplaters' Soc., 1960, 116-123; discussion 242) The absorption and release of H2 from metals are discussed in relation to accepted mechanisms for the  $H_2$  electrode reaction. The effects of the rates of the various kinetic steps are evaluated and the influence of coverage and surface films are

Gas solubility in iron-base and nickel-base alloys M. J. Trzeciak and F. W. Boulger (AIMME., Proc. Elec. Furn. Conf., 1959, 17, 203-211). The authors present data on the solubilities of H<sub>2</sub>, O<sub>2</sub> and N<sub>2</sub> in liquid iron-base and nickel-base alloys under various equilibrium conditions, and on the quantities of dissolved gases actually found in experimental and production heats. The actual quantities are considerably lower than the equilibrium solubility contents .- G.F.

The effect of phosphorus on the deformation and fracture characteristics of iron from 1600 to 2200° F R. Nordheim, T. B. King, and N. J. (Trans. Met. Soc. AIME, 1960. 218. Grant Dec., 1029-1032) Constant-load creep-rupture tests were conducted in an argon atmosphere at temp. of 1600-2200°F on two heats of iron containing about 0.06 and 0.09%P in solid solution, the tests being conducted in the ascast condition. Stresses were selected to give strain rates approaching these encountered in the hot working of steel, and within the limits of the creep-rupture test apparatus, namely, from about 0.001 to 50%/s.—s.H.-s.

Influence of addition of nickel on the characteristics of 'Moelinvar', a new Elinvar type alloy of cobalt, iron and molybdenum H. Masumoto, H. Saito, T. Kono, and Y. Sugai (Nippon Kinzoku, 1960, **24**, (5), 308–311) [In Japanese] The addition of Ni causes the min. value of thermal expansion coeff. to become smaller  $(1.64 \times 10^{-6}$  with the alloy containing 7.5%Co, 1.5%Mo and 30%Ni) and the max. value of the temp, coeff. of the modulus larger. In general the effect on the ternary alloy is as if Co were replaced by Ni.-

New carburizing steels in German automobiles H. U. Meyer (Met. Prog., 1961, 79, Jan., 70-75) The major alloying element in these is Mo and they have been so successful that they have replaced the standard grades despite their higher cost. Examples are 20MoCr4 (C 0·2, Mn 0·7, Cr 0·4, Mo 0·45%); 25MoCr4 similar to the foregoing but C 0·25% and 20NiMoCr6 which additionally contains 1.5%Ni. Each has its specific uses. Case and core hardenability curves are given and the calculation system of Jatezek and Cirardi is discussed. It is pointed out that knowledge is not yet available to show why the different alloying elements behave differently in rela-tion to C content and cooling rate but work in this direction is being undertaken. It is also necessary to learn the effect of C content of the martensite, free carbides and residual austenite on the wear characteristics, pitting, and fatigue strength of gears.

Unusual steel looks promising (Engineering, 1961, 191, March, 24, 407) A new alloy, with a composition of 18Ni-7Co-5Mo-steel with less than 0.5%Ti and 0.05%C, is presented by Inco, which is claimed as the only known material which has a yield strength in excess of 250000 lb/in2 while maintaining a nil ductility temp. below  $-80^{\circ}\text{F}$ . Notched tensile strength has exceeded 400000 lb/in<sup>2</sup> with a notch radius of 0.0005in, with indications that high strength levels of up to 500000 lb/in2 or even higher may be obtained with this type of steel. Brief data are appended.

Navy picks cast stainless alloy E. A. Schoefer (Met. Prog., 1960, 78, Nov., 122) Recent work on the properties of DC-4MCu shows that the alloy shows resistance to stress corrosion higher than that of 18–8. The alloy has been used to manufacture the breech door of a new type of torpedo tube assembly.

Trends in the development of high strength steels for welded structures in Czechoslovakia F. Šicha (Zvár. Sborník, 1961, 10, (1), 100-108) [In Czech] The development and use of MnCrSi steels, and steels in which placed advantageously by Ti, are described. Metallurgical and technological features relating to the use of these steels in welded structures are discussed.—P.F

Modified 4340, heat-treated to 270000 to 300000 ultimate J. C. Chang, F. J. Herr, and J. W. Sweet (Met. Prog., 1960, 78, Nov., 104-110) Data are given of the results of investigations into the properties of forged bars from this steel (nominal comp: 0.40%C, 0.75%Mn, 1.5%Si, 2%Ni, 1%Cr, 0.4%). A comparison was made of the steel made by three methods – basic electric, vacuum induction and consumable arc.

sumable arc.

Progress with 25% nickel steels for highstrength applications International Nickel Co.
Inc (Met. Prog., 1960, 78, Nov., 99–100) A
progress report, based on laboratory tests, of
the properties of low-C 25%Ni steel, including
steels with a combined Al and Ti content of

Experiences with the use of weldable highstrength steels in Hungarian industry B. Zorkoczy (Zvár. Sborník, 1961, 10, (1), 41-50) [In Slovak] The production and properties of a new Hungarian weldable high-strength steel of the St 52 type containing, apart from Mn, 0.02-0.05%Ti and Al, are described. The brittle to ductile transition is below -40°C; tests showed that with up to 0.1%Ti normali zation is unnecessary. Transverse notch ductilities are 12 and 8 kgm/cm² at 20° and  $-40^{\circ}$ C respectively. For weld calculations a fatigue strength of  $16 \, \text{kg/mm}^2$  may be assumed. The use of steel in the construction of cranes and conveyors is discussed .-- P. I

Microstructures and notes on manganese-nickel-chromium-molybdenum steel hea treated to BS.3100:1957:1458 and 1459 Turton and B. H. C. Waters (Brit. Found., 1961, 54, Feb., 60-66) The mechanical properties of three casts of air-cooled or water-quenched and tempered steels to BS1458 and 1459 are compared with the specified values.

Typical microstructures are presented.

Preliminary work in preparation for the introduction of the special structural steel 18MnSiTi5 S. Kronmarck (Technik, 1960, 15, Sept., 597-602) The experimental work described showed that a minimum yield point of 45 kp/mm<sup>2</sup> could be obtained by additions of or Ti. Tests were carried out in plate and strip, and in section and bar steel.

### METALLOGRAPHY

Improved metallographic techniques in Nova Scotia C. A. Godden (Met. Prog., 1961, 79, Jan., 121–123) Since the refractive index of Al<sub>2</sub>O<sub>3</sub> films is 1.56 and that of the immersion oil is 1.52, difficulty is found in optical examination; with mounting plastic a similar difficulty also occurs. The problem has been solved by depositing a thin coat of metal over the oxide film and the configuration of oxide crystals can be clearly seen on the coated specimen. If the oxide film configuration is to be correlated with metallic structure in cross-section, a metal should be chosen which will resist the etching agent, e.g. Au, Pd. This technique is further discussed. The use of diallyl phthalate as a mounting material is described and the characteristics of other moulding resins are mentioned. Diallyl phthalate when filled with a conductive filler such as flake Al makes an excellent medium for mounting for electropolishing. Electroconductivity is assured

Two fundamentals of all metallurgical opera tions A. M. Portevin (Met. Prog., 1961, 79, Jan., 126, 128, 130) The kinetics of reactions involving two phases, the degree of dispersion of the phases and the many factors that affect these problems are succinctly discussed and attention is specially drawn to the Ugine-Perrin process and the work of Stohr and

Klemm,—c.v.

Fundamentals of the solidification of metals W. C. Winegard (Met. Rev., 1961, 6, No.21, 57-99) A review is presented which is stated to be concerned with growth, and its philosophy to be throughout to look at structures obtained during solidification as a function of growth conditions, and, in particular, to relate these structures to supercooling. The subject is discussed under four main headings: I. Growth in pure metals. II. Growth in alloys. III. Segregation. IV. Eutectic growth. (107

Newest development on phase analysis of teels H. Sundermann and O. Gautsch Rudarsko-Metalurski Zbornik, 1960, (4), 375– 382) A review of modern methods for determination of nonmetallic inclusions, and intermetallic phases, in steels, covering direct processes like metallographic study of polished

processes like metallographic study of poinsned surfaces and indirect processes like electrolytic dissolution. (43 refs.)—M.L.

Extraction replicas of the C-Au-C and C-PtPd-C type for electron-microscopical analysis I. Hrivňák (Hutn. Listy, 1961, 16, (1), 49-52; Met. Treatment, 1960, Nov., 445-448)
[In Slovak] Extraction replicas made by first deposition captage. depositing carbon on the specimen surface, then shadowing with Au or Pt-Pd alloy, followed by a further layer of 'carrier' carbon, are shown to facilitate the best utilization of the resolving power of electron microscopes. Examples relating to studies of ferrite-pearlite structures, to grain boundary precipitation of carbides and sigma-phase in steels, etc., are discussed on the basis of micrographs obtained by the author.-

Isolation of carbide particles in steel (Can. Mines, Research and Special Projects Report 1960, 1961, 48-49) The work on the extraction and analysis of intermetallic phases from an ultra-high strength Cr-Mo-V secondary hardening steel in the hardened and tempered condition has been extended to include temp. from 60-345°. The partition data showed that in the tempering range (60–250°), the matrix is slightly impoverished in C and the alloying elements this effect being more marked between 205–290°; this coincides with a fall in hardness from Rockwell C 53 to 50. Above 290°, C and the alloying elements redissolve in the matrix and this corresponds with an increase in hardness to about Rockwell C 52 on tempering at 345°.—c.v.

Determination of the composition of carbides of type M<sub>23</sub>G<sub>6</sub> in different austenitic alloys J. Philibert, G. Henry, M. Robert, and J. Plateau (Compt. Rend., 1961, 252, Feb. 27, 1320-1322) The Castaing microsonde has been used to analyse the residues of extraction as applied to the case of  $\rm M_{23}C_6$  carbides in austenitic steels, with the changes in the composition of this carbide as a function of tempering time at 750°C, with the relationship between its com-

position and that of the alloy after tempering for 24 h at 750°C.—s.n.-s.

Precipitation of carbon from solution in alpha-iron (Can. Mines, Research and Special Projects Report 1960, 1961, 49-51) Iron strip 0.005in thick was carburized to about 0.02 wt %C and samples were quenched from  $720^{\circ}$  and then aged at various temp., mostly at 100–200°. Transmission electron microscopes specimens were prepared by electrolytic thinning. It was found that precipitation of C was a two-It was found that precipitation as the stage process. On ageing at  $100^{\circ}$  small loops, similar to collapsed vacancy discs, formed on the (100) planes of the iron in  $<\frac{1}{2}$  h, some being attached to dislocations. These loops appeared to act as nuclei on which the initial carbide, probably the epsilon form, grew. Precipitates were first seen as feathery platelets which grew on ageing; growth was more rapid on loops attached to dislocations than on those which were remote and growth continued for ~100 h at 100° with a subsequent thickening and a decrease in featheriness. This has been followed for 1000 h. At 200° the initial particles were well formed after 5 min and after harge plates of carbide had formed on the (100) planes of the iron. This appeared to be the same carbide phase as that formed at 100° but was not definitely identified. A second carbide phase, cementite, formed in 2 h at 200° and was very stable and appeared to nucleate at particles of the initial carbide phase. The cementite grew rapidly at this temp. in the form of bundles of rods along the (III) direction of the (110) planes. The initial carbide phase was almost entirely dissolved after 5 h but ageing up to 20 h at high temp. produced some further growth of the cementite particles.~

Study on carbides in iron and steel by electrolytic isolation method. II. Partition of alloying elements between carbides and ferrite in annealed steels T. Sato and T. Nishizawa (Techn. Rep. Tôhoku Univ., 1960, 25, (1), 65–75) [In English] The distribution is governed by Nernst's partition coeff. of Cr. Mn, V, Mo, W, Ni, Co, and Si are given, and partition equations are given for each element. Constitution diagrams for Cr and V steels at 700°C are deduced from the composition and structure carbides in annealed high-alloy steels (13 refs).—K.E.J

Study on carbides in high-C high-V high-speed steel S. Koshiba, S. Kimura, and H. Harada (Nippon Kinzoku, 1960, 24, July, 437-440) [In Japanese] Contents and types of carbides present were determined and related to heat treatments and to cutting properties

Carbides in molybdenum steels T. Satô, T. Nishizawa, and K. Tamaki (Nippon Kinzoku, 1960, **24,** July, 469-473) [In Japanese] The equilibrium of carbides with austenite was studied by isolation and chemical and X-ray analyses. The stable and metastable equilibria at 900°C were determined and carbide structures are discussed.

On the carbide reactions; the secondary hardening and the volume change occurring in the fourth stage of tempering of alloy steels T. Satô and T. Nishizawa (Nippon Kinzoku, 1960, 24, July, 473-477) [In Japanese] Carbides from Cr. Mo, W, and V steels tempered at 400-730° were isolated and examined by chemical and X-ray methods, and dilatometric measurements were made on tempering. Findmeasurements were made on tempering. Find-

Contribution to the study of the morphology of non-metallic inclusions in iron and steel of non-metallic inclusions in iron and steel products. Inclusions in ferro-molyhdenum R. Zoja and A. Masi (Met. Ital., 1960, 52, Dec., 855-864) [In Italian] A number of Fe-Mo samples were examined and tested and their inclusions classified. The majority of these differ distinctly from those of inclusions in -Cr or Fe -W

Electrolytic isolation of carbides, sulphides and phosphides in white cast irons H. Kita-gawa and N. Shibata (Nippon Kinzoku, 1960, 24, (4), 253-256) [In Japanese] Conen. ratios of S and P between carbide and matrix are 2.2 and 1.4. The residue from white irons containing Mn can be separated from sulphides etc. The residue obtained by iodine treatment has an X-ray pattern resembling FeP (15 refs).

Nature of the carbide phase in titanium-alloyed steels Y. T. Lukashevich-Duvanova and V. A. Urazova (Izv. Akad. Nauk. Otd. Tekh Nauk. Met. i Toplivo, 1959,Oct., 127-130) The formation of pure Ti carbide in a C-steel (0.07-0.25%) and the solution of this in the presence of nitrides, sulphides, and oxides of Ti are studied. To determine the relative amounts of Fe and Ti carbides formed in the metal, a phase analysis was carried out; this resulted in the conclusion that there was a difference in their solubilities. With increasing Ti in steel, there is a constant reduction in the amount of Fe carbide phase and a regular increase in the Ti carbide phase, but the amount of Ti oxide inclusions present in the form of Al<sub>2</sub>O<sub>3</sub>, TiO<sub>2</sub> remains almost constant. When there is a great excess of Ti as compared with C (1.8%Ti, 0.2%C), the ppt. contains ~10%Fe carbide; with a Ti content four times as great as the C, the residue consists of 53%Fe and only 38%Ti carbides.—C.B.

Distribution of manganese and of certain Distribution of manganese and of certain added elements between the phases in steels with a high elastic limit L. Bäcker, R. Bigot, and E. Herzog (Rev. Mét. Mén. Sci., 1961, 58, Jan., 11-24) The range of compositions studied was: C0.06-0.4%C, 0.5-2.1%Mn, up to 0.6% Mo, up to 1.8%Cr, up to 0.23%V, and up to 0.750 Ni. By separating the phases by the 0.75%Ni. By separating the phases by the techniques described, the distribution of these accompanying elements between the ferritic matrix and the C phases in examined, and the part played by each determined (22 refs).

Shapes of aluminium nitride in steel S. Hasebe and M. Yanigizawa (Sumi. Met., 1960, 12, April, 387–399) [In Japanese] Electron micrograph of aluminium nitride precipitates in steel containing 0.20%C, 0.30%Si, 1.35%Mn, acid-soluble 0.12%Al, 0.006%N, and 0.041%N was shown by the so-called carbon extraction replica technique. AlN precipitates in steel are rectangular in shape and are of simple crystalline structure. Their size is varied with pre-heat treatment. It seems that large AlN precipitates exist at the grain boundary in the austenitic range. AlN pre-cipitates exist in a dispersed condition in both ferrite and pearlite structures in the normalized state.-

Speckled inclusions in 38KhMYuA steel  ${f F.\ I.}$ Shved and M. I. Kolosov (StaV, 1961, (2), 164–167) P,  $H_2$ , and S appear to be responsible for rejects from this cause. Complete oxidation and control of top discard by steel composition minimize the effect.

Influence of the quality of ceramic runners on the micropurity of steel intended for railway tyres. Part 2 of the investigation concerning determination of the origin of non-metallic inclusions in steel by means of the radioactive isotope <sup>46</sup>Ca T. Myslivec, J. Čadek, M. Mandl, J. Vršek, and M. Lubovsky (*Hutn. Listy*, 1961, **16**, Feb., 94–102) [In Czech] Upon using fireclay runners the portion of inclusions resulting from the aggressive effect of steel on these runners is approximately 40% higher than using semi-acid ones. The quality of ceramic runners is not a factor which will determine this micropurity of the steels examined. The physical-chemical factors, particularly the temp. of the steel have more influence on the micropurity. It is more advantageous to use semi-acid runners because the costs of production per ton of semi-acid material 54, 15 ke (i.e. by approx. 48%) lower than with the fireclay material.—R.S.F.C.

The effect of the composition of chromiumaluminium steels on their susceptibility to spotty segregation A. T. Perevyazko and N. M. Chuiko (Stal', 1961, (3), 267–271) Inclusions of alumina are the primary cause of the defect, which can be much reduced by deoxidation with Si-Ca.

Magnetic separation of phases isolated electrolytically J. Tykva and J. Ježek (Hutn. Listy, 1961, 16, (1), 53-56) [In Czech] Substances isolated electrolytically from steels, e.g. carbides, are often contaminated by other, unwanted, phases. The magnetic separator developed by the authors is shown to facilitate the separation of such phases on the basis of the differences in their magnetic properties. Particles obtained by electrolytic methods were invariably found to be contaminated to some extent by the matrix material.-P.F

Precipitation of iron-molybdenum and iron-tungsten solid solutions Ε. Hornbogen (Z. Metallkunde, 1961, 52, Jan., 47-56) A special type of discontinuous precipitation was found in supersaturated solid solutions of α-iron and Mo or W. The mechanism of the reaction is discussed (35 refs).

On the theory of recrystallization V. Dehlinger (Z. Metallkunde, 1961, 52, Jan., 44-47) The nature of preformed recrystallization nuclei is discussed, and it is shown that the size of the dislocation 'clouds' surrounding the less deformed nuclei is such that large-angle crystal boundaries are formed at the points of contact. The most stable regions, due to their orientation in the deformation texture, show an increased number of nuclei with a tendency to growth. Hence a similar orientation selection can be anticipated as in growth

The significance of technical recrystallization processes K. Detert (Z. Metallkunde, 1961, 52, Jan., 27-34) The influence of various conditions during manufacture, and the effect of deformation work and annealing, on the mechanical and physical properties obtained by recrystallization are described. Examples given, including grain-oriented magnetic sheet, show that changes of structure and of mechanical and physical properties are interdependent

On the austenite grain growth of 18-8 stainless steels T. Mori and E. Ichise (Suiyokwai-Shi, 1960, 14, March, 76-81) Steels

AISI 304, 304L, 316, 316L, 321, 321L, 347, and 347L were examined in the range 800-1100°C. C causes some grain coarsening and Nb refines more than Mo or Ti. Activation energies came out similar to earlier findings on plain C steels.

Texture formation in primary recrystalliza-tion H.-P. Stüwe (Z. Metallkunde, 1961, 52, Jan., 34-44) Primary recrystallization textures are classified according to their orientation relationships to the deformation texture, and their nature discussed. Non-ferrous examples are given (37 refs).

Kinetics and mechanism of the growth of an austenite grain K. A. Malyshev (Izvest. Akad. Nauk. Khim. Anaff., 1946, 16, (2), 49-53) Factors studied include stability of the boundaries of a small austenite grain, kinetics of the growth of an asutenite grain, and the effect of heat-treatment. Relationship between mean small-grain size and heating temp. with holding for 3 h, and growth of an austenite grain with changes in temp. were established.

Parameters of the change in grain size of certain steels in the process of their crystalliza-tion during hot working M. B. Vratskii (Izvest Akad. Nauk. Fiz. Khim. Anal., 1946, 16, (2), 13-48) A large number of steels was examined and parameters established. Regularities were noted and equations are suggested for change

in grain size (13 refs).—A.I.P.

The influence of aluminium on the secondary ustenite grain in steel D. S. Kamentskaya and I. B. Piletskaya (Problems of Metallography and the Physics of Metals, 1959, 52-59; translated from Russian) It is shown that Al dissolved in steel results in secondary austenite centres and retards their rate of growth. This is theoretically examined and it is found that Al diminishes the boundary and surface energy and increases the activation energy. It is also found that in the heating of steel, Al retards the growth of secondary austenite in pearlite and from this it is argued that Al will retard the diffusion of C in iron.—c.v.

Strengthening low-alloy steels by deforming austenite R. A. Grange and J. B. Mitchell (Metals Eng., Quart., 1961, 1, Feb., 41-53) Plastic deformation of austenite under circumstances which preclude recrystallization results in changes in microstructure. This was investigated in several low-alloy steels. The greater strength of the martensite in hot coldworked steel is primarily attributed to a grain refinement which results from the preferred alignment of the martensite plates; these have been formed from austenite grains which are elongated in the direction of principal deforma-

Critical review of the theories concerning the crystallization of steels S. Enekes (Koh. Lapok. 1960, 93, Nov., 490–493) The author rejects Tamman's theory of simultaneous crystallization, and accepts Larcov's and Csernov's theory of continuous crystallization supple-menting it with the assumption that in the process of crystallization not only exogenous, but also indigenous nuclei take part. The crystallization starts near the walls of the ingot mould, and finishes at the centre of the ingot.

Study of the influence of the form and the distribution of graphite on the quality of piston rings of alloy cast irons T.Dumitrescu (Acad. Romine Stud. Cerc. Met., 1960, 5, (4), 493-515) The influence of the characteristics of eutectic graphite on the quality of cast alloys piston rings was studied, investigating Cu, Cr-Ni, and Cr-V alloys in comparison with Cu cast alloy with uniformly distributed lamellar graphite. It was found that although the thermal stability of the microstructure was the same in cast alloys with eutectic or lamellar graphite, the hardness, tensile strength, and wear resistance were much higher in the former, and corresponded to the fineness of the pearlite, the amount and distribution of the ferrite, and the phosphide eutectic. The form and distribution of the graphite was of secondary importance. Alloying with Cu or Cr-V gave better results with cast iron than Cr-Ni.—M.L.

Investigation of transformations in high-speed steels J. Papier and A.-H. Michel (Rev. Mét. Mém. Sci., 1960, 57, Dec., 901-908) The influence of bainite or martensite on the transformation of residual austenite during heattreatment at elevated temp. of various high

speed steels was examined. In steel 18-4-0 without V, 18-4-2 and 18-4-1 with 1.7%Si the presence of these phases lowers the temp. which transformation y→a begins on

at which transformation you begins annealing.

Effect of deformation on the speed of the isothermal transformation in iron-nickelmanganese alloy O. P. Maksimova and A. I. Nimonorova (Problems of Metallography and the Physics of Metals, 1959, 101-113; translated from Russian) A new experimental proof is offered to support the view that martensitic transformation is inherently a thermal transformation is inherently a thermal phenomenon and the effect of preliminary plastic deformation on the speed of isothermal transformation of austenite into martensite is discussed in relation to speed and temp.

Continuous cooling transformation diagrams of steels for welding and their applications M. Inagaki and H. Sekiguchi (Trans. Nat. Res. Inst. Met., 1960, 2, No.2, 102-125) [In English] The present communication is a summary review, and discussion based upon some 30 review, and discussion based upon some to earlier articles dealing with this subject which have appeared in the Jap. Weld. Soc. J., Some 73 diagrams, tables, and photomicrographs are given together with 24 refs. and an appendix in which the continuous cooling transforma-tion diagrams of steels submitted to welding are shown,---c. v

Graphite formation in cast iron at high freezing rates I. Minkoff and A. Goldis (IGK Ireczing rates 1. Minkoff and A. Goldis (IGK Kongress Vorträge, 27th International Foundry Congress, Zurich, 1960, 295–302) [In English] The formation of graphite at high freezing rates was examined, using a modified form of the small-drop technique. Particular attention was paid to the change in form of graphite from flake to spheroid as freezing rates increased. From the appearance of austenite in the vicinity of and surrounding the graphite the vicinity of and surrounding the graphite nodules it is concluded that the nodular graphite in quenched untreated irons forms directly from the liquid (16 refs).

On the continuous cooling transformation in a 0.6% C-Cr Mo V steel T. Kunitake (Sumi Met., 1960, 12, April, 400–414) [In Japanese] Dilatometric method and metallographic observations of microstructures used. The transformation behaviour on continuous cooling as well as the resultant structures and hardness were investigated as the junction of the cooling rate. Mechanical properties of various continuously cooled structures were evaluated and results given.

Studies of the decomposition of cementite R. Mitsche (IGK Kongress Vorträge, 27th International Foundry Congress, Zürich, 1960, 123-151) [In German] After a general review of the present position of cast iron research, an experimental approach to the solution of the problems of the formation of very fine eutectic lamellar graphite and the nucleation and growth of nodular graphite. It was shown that in no case was fine lamellar graphite formed by direct or indirect decomposition of cementite, which confirms the theory of direct formation of this type of graphite from the melt. A method is described for demonstrating the influence of pressure in graphite formation; it is shown that, at least in the initial stages, the formation of graphite on free surfaces is very similar in untreated and in Mg-treated cast irons (22 refs).

Retained austenite A. Kalivoda (Hutn. Listy, 1961, 16, Feb., 135–138) [In Czech] Retained austenite occurs in most constructional steels after hardening and unfavourably influences the mechanical properties. In Cr-Ni-Mo steel it was found that more retained austenite persists with slower cooling—by intensive hardening and cooling in liquid nitrogen it can be removed entirely. Decomposition occurs mostly at 250 and 300°C although retained austenite stabilized by hardening in oil bath 200°C does not decompose even at 400°C. At higher austenitizing temp, the austenite lattice contains fewer distortions that might act as suitable nuclei of

martensitic needles after cooling.—R.S.F.C.

Microcalorimetric study of the transformation of austenite of a 12 % Mn and 1.3 % C steel
G. Collette (Thesis presented to the Science Faculty of the University of Paris, 1959,
Dec. 12, pp.70) The experimental methods and apparatus used are described. Then follow

studies first of the kinetics of the transformation of the austenite in non-annealed and then of annealed steels. The final chapter outlines a new method of calculating the coefficients of Wert Law regarding the kinetics of precipitation.

Kinetics of stabilization of austenite M. Izumiyama (Nippon Kinzoku, 1960, 24, (3), 175–178) [In Japanese] Investigations on 1%C, 5%Ni steel suggest that stabilization is acaused by reducing mobility of dislocations during low-temp, ageing (by interstitial solute atoms). But stabilization will also be produced by mechanically blocking the motion of dis-

by mechanically blocking the motion of dis-location lines, e.g. by pptn. of a second phase during high-temp. agoing (30 refs).—K.E.J. Breakdown of residual austenite during tempering and its effect on impact strength of steel V. D. Sadovskii (Izvest. Akad. Nauk, Fiz. Khim. Anal., 1946, 16, (2), 54-60) The literature is reviewed and an explanation given of the effect of the breakdown of residual austenite on impact strength. The need is shown for an investigation of the nature of the brittleness following such a breakdown (14

Study of the heat of transformation of the austenite pearlite reaction M. Genot (Compt. Rend., 1961, 252, Feb. 27, 1282-1284) A laboratory study of ten tests of a sample of pearlitic steel, with the welding of the thermo-couple at nine different depths, is reported. Changes in the fine structure of austenite and

of the kinetics of the martensite transformation under the influence of plastic deformation O. P. Maksimova, A. I. Nikonorova, and E. I. Estrin (Problems of Metallography and the Physics of Metals, 1959, 114–122; translated from Russian) Data obtained on the role played by deformation and subsequent heating of austenite are in agreement with observa-tions on the direct and reverse martensitic transformations and the stabilization of the austenite. The self-diffusion of iron in Fe-Ni-alloys is also discussed.—c.v.

New horizons—martensite transformations W. S. Owen (Metallurgist, 1961, 1, (7), Jan., 238-242) A paper, studying the crystallography and thermodynamics of the transformation, the nucleation problem, and secondary effects.—S.H.-S.

Microstructural investigation of martensitic ransformations O. P. Maksimova and A. I. Nikonorova (*Problems of Metallography and the Physics of Metals*, 1959, 69–100; translated from Russian) This problem was investigated in Mn, Ni, and Mn-Ni steels and in a C-free alloy of Fe, Ni, and Mn. Each possesses a unique form of martensite and a different reaction transformation continuous With Ni creaters. cooling-transformation course. With Ni steels the transformation is rapid and due entirely to the formation of the new crystals, while with the Fe-Ni-Mn alloy the reaction is sluggish and the growth of previously formed crystals is also found. With prior plastic deformation of the austenite, fragmentation of the martensite crystals is noted, these being formed during the subsequent cooling. The distinguishing feature between 'martensite of deformation' and 'martensite of cooling' is the great dispersion and more regular arrangement of the crystals in the field of austenite gain in the former case. The martensite formed by large deformation is very highly dispersed and no longer retains the typical form of structure. The many other relationships are examined and discussed.—c.v.

Bainitic transformation in alloy steels M. Bay and R. Tomei (Met. Ital., 1960, **52**, Dec., 813-827) [In Italian] Systematic research i described on bainitic structures under iso-thermal conditons on a number of casehardening, spring, and alloy tool steels. results obtained are compared with those derived from conventional methods of treatment and the possibility of extension of bainitic treatments is discussed.

The influence of bainite on the ductility of alloy-structural steels K. Tsuya (Nippon Kinzoku, 1960, 24, July, 440-444) [In Japanese] Bainite formed in continuous cooling has an adverse effect increasing with the amount of bainite produced. Isothermal formation at higher temp. has a still more adverse effect, though near the Ma temp. the effect is neglig-

Composition and structure of solid solutions in complex alloy steels A. P. Gulyaev (Izvest. Akad. Nauk, Fiz. Khim. Anal., 1946, 16, (2), 61-69) In all tool, structural, and other complex alloy steels the alloying elements are distributed unequally between the various steel phases, As a rule average steel composition is studied and not phase composition. The authors studied various complex alloy steels of the carbide class and paid particular attention to the effect of alloying elements and of quenching temp. on the phase composition of the steel.

Thermally stable properties of solid solutions of chromium, nickel, and manganese in gamma iron A. M. Borzdyka (*Izvest. Akad. Nauk, Fiz. Khim. Anal.*, 1946, **16**, (2), 116-125) Factors studied include thermal stability of Cr-Ni austenite and of Cr-Mn austenite, internal transformations in high-alloy austenite and their influence on thermal stability, and the influence of the size of the austenite grain on

thermal stability

Concerning manganese-iron alloys A. T. Grigor'ev and D. L. Kudryavtsev (Izvest. Akad. Nauk. Fiz. Khim. Anal., 1946, 16, (2), 70-81) The part of the Fe-Mn system with up to 50%Mn was studied by the dilatometric and thermal-differential methods of analysis and according to hardness, electrical resistance, and microstructure. Alloys can be divided into groups, which are given, according to their behaviour during a change in their temp. and the character of their component phases. A

review of the literature is also given (25 refs).

The formation of (110) [001] recrystallization texture in a cold-rolled and annealed (110) [001] crystal of silicon—iron Hsun Hu (Acta Met., 1960, 8, Feb., 124–126) A letter. A 70% cold-rolled 3% Si-Fe crystal of initial orientation near (110) [001] was completely recrystallized on annealing at 800°C for 15 min, and the resulting texture, consisting of a single (110) [001] orientation, can be described as a [110] rotation of 35° from both of the (111) [112] type main deformation texture components. Other tests indicated that annealing at 550°C for 2 h eliminates the orientation scatter round (110) [001], while later anneaung at 950° for 1 min produces a sharp (110) [001] recrystallization texture identical with that obtained in the original experiment. It is concluded that Walter and Hibbard's interpretation that the very weak component in the deformation texture, which has the orientation of the original crystal, may serve to nucleate the recrystallization texture, is incorrect.

Discussion of paper entitled: 'The formation of (110) [001] recrystallization texture in a cold-rolled and annealed (110) [001] crystal of silicon-iron' by Hsun Hu J. L. Walter, W. R. Hibbard, and C. G. Dunn (Acta. Met., 1960, 8, Feb., 126-127) A letter. The authors reply to the critisium in this letter (that it is to the criticism in this letter (that it is unlikely that minor components of the deformation texture (preformed nuclei) with the same orientation as the initial single crystal may serve as the origin of the recrystallization structure). They state that the pole figures in Hsun Hu's letter are not sufficiently accurate to show pole densities below 1 random, and show that orientation as low as 1/100 random may convert the sample to a strong texture of

may convert the sample to a strong texture of the same orientation.

Growth of (110) [001]-oriented grains in high-purity silicon iron — a unique form of secondary recrystallization J. L. Walter and C. G. Dunn (Trans. Met. Soc. AIME, 1960, 218, Dec., 1033–1038) Secondary recrystallization to the (110) [001] texture in high-purity silicon iron occurs if low-oxygen material is supposed in a nonoxidizing atmosphere. Any annealed in a nonoxidizing atmosphere. Any departure from these conditions results in a growth of (100) oriented grains. The nature of the matrix and secondary recrystallization structures and textures and the nature of grain boundary interactions during growth show that the low gas-metal interfacial energy of the (110) surfaces provides the driving force for growth of these grains.—s.H.-s.

Determination of retained au

Determination of retained austenite in quench-hardened steels E. Fuchs (Koh. Lapok, 1961, 94, Feb., 57-61) Microscopical, dilatometric, magnetic and X-ray diffraction methods are described in the paper.-P.K.

Experimental evidence for martensitic embryos M. H. Richman, M. Cohen, and H. G. F. Wilsdorf (*PB* 150850, 1959, Nov., pp.6; from *US Res. Rep.*, 1961, **35**, Jan. 13, 95) [No

The orientation of martensite in austenite H. M. Otte (Acta. Met., 1960, 8, Dec., 892–896) A letter. New measurements have been made of the orientation of single martensite plates in an austenite matrix, using the back reflec-tion Laue method and an X-ray microbeam technique with pinholes 10-50 µin diam. The accuracy of the results, which are briefly reported, is considerably greater than can be achieved with the pole figure method or its variations. The orientation relationships have been worked out in terms of an axis and an angle of rotation, which, when applied to the austenite axes, would bring them into coincidence with the martensite axes.—s. H.-s.

The growth rate of bainite G. R. Speich and M. Cohen (*Trans. Met. Soc. AIME*, 1960, 218, Dec., 1050–1059) The growth rate of bainite has been determined by hot-stage metallography in five hypereutectoid high-purity iron-carbon, iron-carbon-chromium, and iron carbon-nickel alloys. The studies are confined to lower bainite. The growth rate is independent of time at constant temp., but both edgewise and sidewise growth rates increase with increasing temp. Increasing the carbon content, or adding chromium or nickel, deaffecting the temp. dependence. The results lead to separate diffusion-controlled models for the edgewise and sidewise growth rates.

The solubility of nitrogen in liquid Fe-Gr-Ni alloys J. C. Humbert and J. F. Elliott (*Trans. Met. Soc. AIME*, 1960, **218**, Dec., 1076–1088) The solubility of nitrogen in liquid pure Fe, Cr, and Ni, in liquid Fe-Ni, Fe-Cr, and Ni-Cr alloys and Fe-Cr-Ni alloys, has been measured by the Sievert's type apparatus between 1500° and 1800°C. Tabulations and graphs of the solubility data and activity coefficients are shown. Heats of solution are reported. Interaction coefficients of the several elements in Fe, Cr, and Ni are also reported.—s. H.-s.
Solubility of nitrogen in liquid iron alloys.

Thermodynamics R. D. Pahlke and J. Elliott (Trans. Met. Soc. AIME, 1960, 218, Dec., 1088-1101) The solubility of nitrogen in liquid pure iron has been measured as a function of pressure and temp. Sievert's Law is obeyed at all pressures up to 1 atm and the temp. coefficient of solubility is  $8 \times 10^{-6} \%$ /°C. The solubility of nitrogen in liquid iron alloys has been studied by the Sievert's method and by the sampling method. The solubility is decreased by Al, C, Co, Cu, Ni, O, Si, and Sn, and it is increased by Cr, Cb, Mn, Mo, Ta, W, and V. Interaction coefficients e'n for the effect of these elements on N<sub>2</sub> dissolved in liquid iron, are reported.—s. H.-s.

### CORROSION

Future corrosion research on ferrous metals J. C. Hudson (Corros. Prev., 1961, 8, April, 43) The work being carried out by various research bodies is generally indicated .- c.v.

What I'd like to know about corrosion D. A Vermilyea (Corros. Prev., 1961, 8, April, 39) Corrosion is discussed from the point of view of the atomic processes involved and these show a very strong dependence on the structure of the solid surface on which they occur. It should also be markedly dependent on the crystal face exposed to the environment. This dependence is discussed in terms of removal of atoms and electrons from solids and of growth and properties of reaction films. The gaps in our knowledge and some possible techniques for furthering our understanding are outlined .- c. v

Mechanisms of corrosion D. J. Garribotti, E. A. Gulbransen, H. T. Francis, J. R. Weeks, J. H. DeVan and F. L. La Que (Met. Prog., 1960, 78, Nov., 170, 172, 174, 176, 178, 180) A digest of a seminar 'Mechanisms of Corrosion' sponsored by the Chicago-Western Chapter of ASM, 14 April 1960.

New theory for rusting of iron E. A. Gulbransen and T. P. Copan (Metallurgia, 1960, 62, Dec., 269) A discussion of the explanation advanced by Westinghouse Research Labora-

tories that the true cause of iron corrosion is penetration by hydrogen ions from water vapour, thereby enlarging the sites at which oxygen normally combines with the metal.

Investigation of corrosion causes M. H. Tikkanen (Corros. Prev., 1961, 8, April, 44-45) Some examples of corrosion failures in Finland are given.-c.v.

Effect of composition and structure of stainless steels on resistance to stress-corrosion cracking E. H. Phelps and R. B. Mears (Corros. Prev., 1961, 8, April, 48) A number of chemical solutions were used to compare the stress-corrosion behaviour of martensitic and austenitic stainless steels. A specially alloyed martensitic stainless steel, 12MoV was susceptible to stress-corrosion cracking in severe solutions at room temp. with anions other than chloride. Type-410 stainless in the tempered condition and 304 in the annealed condition were resistant. The 12MoV stainless was also susceptible in a series of solutions containing chloride while 410 was substantially more resistant (except with sulphide) to stresscorrosion than 12MoV. Annealed 302 and 304 were resistant to all solutions except boiling 42% MgCl<sub>2</sub> but in the highly cold worked condition they were susceptible to some of the chloride solutions at room temp. Various other aspects are discussed.—c.v.

Atmospheric corrosion of metals I. L. Rosenfel'd (Corros. Prev., 1961, 8, April, 49-50) Electrochemical methods for studying this corrosion in thin electrolyte layers are discussed and the theoretical aspects are considered. A new kind of cathodic depolarization has been observed due to  $SO_2$  reduction and increased metal corrosion in industrial districts is associated with this .- c. v

The selection of length and head scales for cavitation tests P. Danel and J. Duport (Trans. ASME, 1960, 82D, Dec., 784-794) Some of the precautions that have to be taken to obtain a correct representation of the pressure field in a cavitation model and to be certain of the critical pressure that has to be used are des-cribed and discussed. It is maintained that if a model cannot provide data on the intensity or rapidity of pitting, it can at least, so long as the precautions described in this paper have been taken, give complete information on the location and extent of regions likely to be affected by cavitation and can, for example, thus indicate regions which ought to be protected by prewelding with stainless steel.—s. H.-s.

Some corrosion effects in accelerated cavitation damage W. D. Leith and A. L. Thompson (Trans. ASME, 1960, 82D, Dec., 795-807) The conjoint mechanical-chemical destruction of metals by accelerated cavitation in a magnetostriction apparatus indicates relative effects of the metal properties (hardness, metallurgical structure, corrosion-fatigue limit), and of the liquid characteristics (temp., pressure, wetta-bility), which have been confirmed by field experience in hydraulic turbines and in watercooled diesel cylinder liners .- s. H.-s.

An experimental study of cavitation in a mixed flow pump impeller G M Wood, J. S. Murphy, and J. Farquhar ( $Trans. \ ASME$ , 1960, 820, Dec., 929-940) A mixed flow impeller design was tested with six, five, and four vanes in a closed water loop to study the effects of cavitation on hydraulic performance and the results were compared with the work of other investigators. Two idealized flow models for incipient cavitation were derived to illustrate limits of cavitation design. Both vane blockage and solidity effects were found to be important when designing for optimum cavitation performance. Data showing incidence and speed effects plus the lip static pressure profiles in cavitating and noncavitating flow are also presented.—s. H.-s.

The role of the oxygen concentration cell in crevice corrosion and pitting G. J. Schafer, J. R. Gabriel, and P. K. Foster (J. Electrochem. Soc., 1960, 107, Dec., 1002–1004) Crevice corrosion, like pitting, takes place in two stages. A differential aeration or inhibitor exhaustion mechanism determines the location where the action is initiated while the continued action depends on the acid mechanism. Examples are given. Pitting is considered to be merely a limiting case of crevice corrosion the difference being the macroscopic geometric factors determine the initiation site in crevice corrosion while random microscopic factors determine the site in pitting.—c.v.

The effects of γ-radiation upon electrode systems: II. Aqueous redox systems F. S. Feates and B. Knight (Trans. Farad. Soc., 1960, 56, 1680–1688) Radiolytic oxidation of FeSO<sub>4</sub> was studied by a potentiometric method and the after effects arise from a change in the conen. of radiolytic generated H. This is an important potentiometrically active species throughout the whole course of oxidation; previously these after effects were considered to be due to post-irradiation. The ultimate equilibrium potential attained is due to the effects of H<sub>2</sub>O<sub>2</sub> and not due to an equivalent redox potential and this concept could not be confirmed as an effective and specific H<sub>2</sub>O<sub>2</sub> scavenger which was not electrochemically active, was not available. The feasibility of monitoring the oxidation potentiometrically for dosimetry purposes showed the method is only suitable when a platinized Pt electrode is used in a solution rapidly swept with A; in other cases, the electrode potentials are not defined by the redox constituents of the solution.

Ethanolamine gas scrubbing systems G. F. Hall and L. D. Polderman (Chem. Eng. Prog., 1960, 56, Oct., 52-58) Designs and operating procedures to minimize corrosion problems in H<sub>2</sub>S and CO<sub>2</sub> absorption plants are presented, with case histories on four plants, a construction materials guide, and a summary of recommendations resulting from the survey.

Storage stability of petrolatum type corrosion preventive compounds L. H. Wagner (PB 148365; from US Res. Rep., 1960, 34, Oct. 14, 482) Storage indoors in bulk containers for five years, with infra-red examination at intervals was studied. Weathering on outdoor and shed exposure panels was also tried for 12-24 months. Great variations were found so that storage for over three years is not advised.

For service under fire—control corrosion H. I. Kee (*Prod. Eng.*, 1960, **31**, Nov. 28, 44–45) Protection of metals in furnace construction is discussed. Suitable heat-resisting alloys are listed and reducing temp., reducing fuel corrosiveness, and choice of more resistant materials are suggested. Notes on embritlement caused by sigma-phase are added.

Stop galvanic corrosion F. Strasser (*Prod. Eng.*, 1961, **32**, Feb. 20, 87, 89) A brief review of the essentials of the problem is given, classifying the five types of solutions.—c.v.

Taking steps towards avoiding corrosion (Engineering, 1960, 190, Dec. 9, 778-779) A brief recapitulation of the chief exhibits on the occasion of the Corrosion and Metal Finishing Exhibition 1960.

Minimizing corrosion G. P. Gladis (Chem. Eng. Prog., 1960, 56, Oct., 50-51) Practical suggestions to extend equipment lifetime when processing wet corrosive media are presented, with four tables of corrosion tests in support of the proposals.—s. H.-s.

Corrosion problems and their treatment. IV (Corros. Prev., 1960, 7, Dec., iii-viii) A general discussion of the protection of steel structures exposed to the atmosphere by painting, coating, wrapping, plating, and galvanizing.—c.v.

Corrosion control of copper and steel by vacuum deaeration M. E. Tester (GAT-296, May, pp.14; from Nucl. Sci. Abs., 1960, 14, Oct. 31, 2651) Vacuum deaeration was assessed with water at pH 5·7-6·3 flowing at 1·8-2·3 ft/sec. Mild steel which failed in 65 days in aerated water showed a penetration of 1·4 mil in 99 days at 100°F and of 0·15 mil in 85 days at 90°F.

Corrosion control studies by manometric techniques R. Eliassen, R. T. Skrinde, and W. B. Davis (Req. Tech. Mect. AISI, 1958, 135-150) Fine grade steel wire (0·008in dia.) provided sufficient surface for the rapid takeup of O<sub>2</sub> and the specimens were pickled in 5%HCl for 4 min at 25° prior to tests. The Warburg respirometer was used and the results obtained were compared with weight loss measurements. The Warburg method was rapid and flexible and enabled many simultaneous variables to be examined under controlled conditions. A statistical correlation can

be achieved between the two methods and the initial Warburg studies indicate that alkalinity alone is not the cause of corrosion inhibition by Na silicate treatment; the silicate group produces the more important inhibitory effect. The deleterious effects of chloride on the corrosion of steel are mitigated by Na silicate treatment.—C.V.

Letter: A note on comparative stress-corrosion behaviour of some high alloy steels S. Berg and S. Henriksson (JISI, 1961, 199, Oct., 188) [This issue].

Accent on corrosion-proofing ( $Products\ Fin.$ 1960, **24**, July, 60-62, 64) An elaborate method for rust-proofing the bodies of Plymouth cars is described. The lower 11-17in of the bodies are dipped in alkaline cleaning solution, rinsed in dilute alkali, water rinsed, dipped in phosphatizing solution, cold water rinsed, chromic acid rinsed, and the bodies are then dried in a convection oven which raises the temp. of the metal to 220°F for 3 min and finally, while the bodies are still hot the internal surfaces are sprayed with a water-reducible primer and finally dipped in a water-based latex emulsion giving a min. film thickness of 0.0005in. This primer coat is baked for 15 min at 250°F. The bodies are now ready for finishing: they are coated with red epoxy primer, sprayed with grey epoxy primer over the wet red coating. This grey coat is for sanding and in this step the red shows through; baking follows at 350°F for 27 min. followed by wet sand. It is now sprayed with a modified baking alkyd enamel, two wet coats on the roof and on the side decorative strip followed by baking at 250°F and the remainder of the bodywork is similarly treated. In testing, the car must be leak-tight to withstand water at 30 psi. A further test involves 280 gal/min for 4 min.

Now: anodic corrosion control C. E. Locke, M.Hutchison, and N. L. Conger (Chem. Eng. Prog., 1960, 56, Nov., 50-55) Anodic protection against various acids, alkalis, and salts is reviewed. Protection of iron against oleum is especially considered.

On the oxidation of a W-Co layer electrodeposited on 0.06% c steel and its carburized surface H. Yamamoto (Nippon Kinzoku, 1960, 24, July, 421-424) [In Japanese] Further studies of the gas carburizing of the surface and the hardness of the layer were made. Oxidation occurs in the range 100-110°C in 1 h and weight increase was determined and X-ray and electron-diffraction studies were made. Scale composition was established.

Corrosion of heat-resisting alloys in the presence of fuel-oil, ash and corrosion by vanadium pentoxide-sodium sulphate mixtures in laboratory tests: correlation with corrosion by oil-ash in field tests Corrosion I Committee ouncil of British Manufacturers of Petroleum Equipment (British Petroleum Equipment News, 1959, 7, Oct.; 1960, Jan., reprint, pp.24) Accelerated oxidation of a series of heatresisting alloys can be reproduced in air tests at 850° by repeated deposition at hourly intervals of V<sub>2</sub>O<sub>5</sub>/Na<sub>2</sub>SO<sub>4</sub>; the results are similar to ash corrosion in oil-fired boilers in field tests. With a  $20\% \rm V_2 \rm O_5$  mixture, the order of merit of the alloys is almost the same as in field tests in oil combustion conditions giving high Na:V deposit ratios; with an 80% concn. in the mixture, the order of merit is similar to that observed in oil combustion conditions in which ash deposits of low Na:V ratio are found. Partial immersion in a synthetic mixture of intermediate Na:V ratio (typical of oil ash) presented the general features of the attack in the field tests but there was a slightly different order of merit, the findings being nearer to those found with the higher Na:V ratios. Sattack by these mixtures is accelerated by NaCl and corrosion found with Na2SO4/NaCl is similar to the V-containing oil ash with high Na<sub>2</sub>SO<sub>4</sub>. Presence of NaCl does not appear to promote the types of corrosion found in oilfired boilers. Samples previously contaminated by V<sub>2</sub>O<sub>5</sub>/Na<sub>2</sub>SO<sub>4</sub> and then oxidized 24 h gave the most pronounced attack when 20 or

the most pronounced attack when 26 of  $40\,\%\mathrm{Na_2SO_4}$  was present.—c.v. On the sulphide scale growing upon the inside wall of cast-iron pots for sulphursmelting K. Nishida and H. Oikawa (Nippon Kinzoku, 1960, 24, (4), 225–229; 229–233) [In Japanese] The scale was mainly pyrrhotite,

with Si distributed all over it. The S content rapidly decreased towards the sulphide/metal interface. Cr moves towards the outer layer of scale when its content is small. Si, Fe, and S had periodic distributions with identical intervals. Although the scale is mainly pyrrhotite, the inner layer contains daubreelite FeCr<sub>2</sub>S<sub>4</sub>, which confers resistance to sulphurization. Si remains in the inner part of the scale. C, Cr, Si, Fe, and S have periodic distributions (31 refs).—K.E.J.

Corrosion testing J. D. Edwards (Quality Chromium Plating: Confidence in Plating, Proc. of Symposium, Feb. 1960, Birmingham, 1960, E, pp.10) Accelerated corrosion tests are discussed with special reference to the British Standard. It is concluded that accelerated tests are valuable both for control and acceptance but it is at present difficult to decide which of the tests is the most satisfactory; further work is being undertaken to

decide this point .- c. v.

Some practical experience in carrying out corrosion tests D. Vitzthum (Werks. Korros., 1961, 12, Jan., 10-15) Comments on the recommendations set out in DIN 50905 on specimen size, number of specimens to be used at each time stage, and the number of such stages to be used. Graphic representation of the tests, and the use of nomograms in evaluating corrosion tests are described.

Evaluation of corrosion-resisting quality of metals J. Ponebšek (Elektrotech. Vestnik, 1960, 28, Jan., 82-88) After reviewing the basis of corrosion problems and the study of corrosion processes, tests used at the Iskra factory, Kranj in investigation of corrosion of materials and products and their results are described with concrete data and illustrations.—S.H.-S.

The emf of some metals in acid solutions and the influence of temperature on the same F. Kelemen (Magyar Kémiai Folyóirat, 1960, 66, (6), 219–226; from Hungarian Technical Abstracts, 1961, 13, (1), 3) The emf of Ag, Cu, Fe, and Zn were studied and the influence of the temp. on these values was investigated in HCl and  $H_2SO_4$ .—R.S.F.C.

Contribution to the kinetics of pitting corrosion in passive chromium-nickel steels E. Brauns and W. Schwenk (Werks. Korros., 1961, 12, Feb., 73-80) Pitting corrosion caused by Cl<sup>-</sup>ions was investigated on six types of Cr-Ni steels in an Fe<sup>+2</sup>-Fe<sup>+3</sup> buffer solution. The results of potential and electrode impedance measurements are discussed, and interpreted by assuming a chemisorption process as a starting reaction. A resistance polarization is assumed as well as a concentration of HCl in the pits (13 refs).

The corrosion of steel in the atmosphere U. Trägårdh (Tek. Tidskr., 1960, 90, Nov. 4, 1103–1105) Methods of determining atmospheric corrosion, its rate, and the influence of relative humidity and  $SO_2$  are reviewed.

A method of corrosion potential measurement by using a microelectrode G. Yokoyama (Nippon Kinzoku, 1960, 24, July, 445-449) [In Japanese] A capillary tipped bulb of corrosive solution is used and potentials are measured on contact with the metal surface. With 20%H<sub>2</sub>SO<sub>4</sub> the values agree with the large scale tests but with 10%NaCl there are anomalies. Application of the microelectrode method for measuring the corrosion potential of alloy structures (449-452) Non-ferrous applications of the microelectrode method are described.

Microscopical examination of corroded boiler tubes L. Székely and Z. Hegedus (Koh. Lapok, 1960, 93, Nov., 481–489) Examining microsections from defective boiler tubes of power plants, the authors found that the cause of the defects was either overheating or corrosion.

The corrosion of metals in wooden casings G. Schikorr (Werks. Korros., 1961, 12, Jan., 1-10) Mechanism of the corrosive effect of the acetic acid evolved by wood and its dependence on humidity are discussed, and methods of protection are suggested (13 refs).

Behaviour of various types of tubes in corrosive soils R. Hoffmann (Centre Belge d'Etude et de Documentation des Eaux, 1958, (94), Oct., 284–287) A report on a series of trials on groups of tubes buried in three localities, the tubes consisting of east iron treated with

bitumen, and steel tubes both plain and coated, and protected cathodically.

Circulating loops for high temperature dynamic corrosion studies in water E. Catling (RDB(R)/TN-51; LEO-RDC/P-34; 1955, June, pp.13; Nucl. Sci. Abs., 1959, 13, June 15, 1352) Test rigs for studies in high temp. water are described.

Corrosion-resistance of nickel/chromium plating G. N. Flint (Quality Chromium Plating: Confidence in Plating, Proc. of Symposium, Feb. 1960, Birmingham, 1960, F. pp.10) A general discussion. Attention is drawn to the difference in structure between the two Ni layers in the duplex-system; the semi-bright layer is columnar containing relatively coarse crystals while the bright layer is a fine-grained laminated deposit. Another composite coating is also promising, Ni-Cr-Ni-Cr or Cr-Ni-Cr, these coatings showing distinct advantages over the conventional systems.—C. v.

VGI Bibliography and abstracts R. L. Le Mar (PB 151766, 1958, Oct. 16, pp.112) A bibliography on volatile corrosion inhibitors 1937–1957, with abstracts.

Corrosion prevention. 2. T. H. Turner (Corros. Prev., 1960, 7, Oct., 46–49) The effects of environment on corrosion and BSI work on corrosion problems are discussed.

Protection of structural steel against corrosion J. C. Hudson (Chem. Ind., 1961, Jan. 7, 3–11) A general review. No attempt is made to consider attack by specific chemicals, the three naturally corrosive media, air, soil, and water alone being considered. The protective coatings studied are paints, metal, and 'other' coatings.—C. Y.

Preventing fretting corrosion Shell Research Ltd (Commonwealth Eng., 1960, 48, Dec., 39 40) Most of the greases examined displayed poor, or only moderate anti-fretting properties but one, a Li-base grease containing non-E.P. polar additives, gave very satisfactory results showing negligible wear on the race and only light polishing on the contact areas after 1000 h. A similar Ca-based grease gave good results subject to a limited temp. range  $(-5^\circ)$  and can be used only for steel surfaces. The addition of  $10^\circ \text{MoS}_2$  drastically reduced the anti-fretting properties of some of the better greases but conferred some improvement on the poor anti-fret lubricants.—c.v.

### ANALYSIS

Study by mass spectrometer of the non-uniform degassing of the hydrogen contained in iron R. W. Lee, D. E. Swets, and R. C. Frank (Rev. Mét. Mém. Sci., 1961, 58, Jan., 36-42) Investigations of the diffusion of H<sub>2</sub> in steel using the mass spectrometer showed a divergence from the fundamental laws of diffusion; this is attributed to the real nature of the diffusion phenomenon, and hypotheses are put forward to account for the divergence.

The photometric determination of silicon in cast iron and steel by the molybdenum-blue method R. A. Catani (Bol. ABM, 1961, 17, Jan., 71-80) [In Portuguese] The method is based on the formation of molybdenum blue starting from silicomolybdic acid. Beer's Law is obeyed over a large range of Si contents. The results of a series of analyses have been compared statistically with those obtained by a gravimetric method. The photometric method is more rapid (20 to 25 min total) and precise (14 refs).—P. S.

Vacuum analysis of certain metals (Wild-Barfield J., 1961, 8, March, 11–14) The Wild-Barfield Vacuum Gas Analyser (Model NRC, 912) is described. The crucible is inductively heated under high vacuum and gas is given off quantitatively; the combined oxides react with the graphite crucible to give off CO and the hydrides and nitrides are decomposed to N<sub>2</sub> and H<sub>2</sub>. The gases are drawn off, H<sub>2</sub> and CO are converted to H<sub>2</sub>O and CO<sub>2</sub> respectively. The H<sub>2</sub>O-vapour is absorbed by Mg-perchlorate and the CO<sub>2</sub> is trap cooled and frozen out at -196° while the N<sub>2</sub> remains gaseous its pressure being determined. The further details are lucidly explained. The question of using a solvent metal (Cr, Mn, Al, and Mg) is discussed but Pt is a cleaner metal to work with as the vapour pressure is so small and despite the cost

some 80% is recoverable. Fe also can be used if the temp. does not rise above  $1700^{\circ}$ .—c.v.

Three way system analyses blast furnace top gases Leeds and Northrup Co. (Steel, 1960, 147, Oct. 24, 106) Three critical top gases are measured in rapid sequence, the sample line being tied into the main stove header and carrying gas through a filter system and into the analyser where a thermal conductivity cell measures the percentage of CO<sub>2</sub> and CO with results all recorded on the same strip chart is described.—s.h.-s.

lon exchange resins in steel analysis F. M. Hall and A. Bryson (Anal. Chim. Acta, 1961, 24, Feb., 138–142) The metals V, Cr, and Mo may be separated from the other constituents of steel by passing an acetate buffered solution of the steel through a strongly basic anion exchanger and selectively eluting the above metals from the resin column with aqueous solutions of 0.6 N NaOH, 8N HCl, and N HCl, respectively.—s.h.-s.

A new sensitive method for detecting iron V. Armeanu, D. Camboli, and C. Ianeu (Bul. Inst. Jasi, 1958, 20, April-June, 85-87) β-Furoin oxime gives with ferric ion a vivid red coloration. The sensitivity of the reaction was found to be 2·10-5, the limit of determination is 0·32 y Fe. The reaction was studied in presence of other ions.—C.F.-O.

Contributions to the complexometric determination of cation mixtures. III. Simultaneous titration of iron (III) and aluminium in the presence of ammonium thiocyanate as indicator C. Liteanu, I. Lukacs, and C. Strusievici (Anal. Chim. Acta, 1961, 24, Feb., 200-202) With thiocyanate as indicator, Fe (III), and Al (III) can be titrated simultaneously if [Fe+³]/[Al+³]≤1/4; Fe (III) is titrated directly with EDTA, and Al (III) is determined by back-titration of the excess of EDTA with cobalt nitrate in an acetone-water medium.

Voltametric determination of cobalt and nickel in hard magnetic alloys R. D. DeMars (Anal. Chem., 1961, 33, March, 342-344) The method described is rapid, accurate, and extremely precise. The current-voltage curves in solutions containing pyridine and KCl were obtained with an all-purpose instrument based on an analogue computer amplifier; several electrolyte systems were examined but that indicated was the most satisfactory. The reduction reactions in KCl are irreversible and it was found that when both Co and Ni are present the waves interfere with each other. By the addition of pyridine the reduction reactions are shifted to more anodic potentials, becoming almost completely reversible; the peaks are separated by about 0·3 V. The peak potentials for Ni and Co in this medium are -0·81 and -1·10 V respectively. The concentrations of pyridine and KCl are critical. Mixture analysis is discussed and examples are given.—C. V.

A new sensitive method for detecting nickel V. Armeanu, B. Camboli, and C. Iancu (Bul. Inst. Jasi, 1958, 20, April-June, 81-83) The ions of Ni give with  $\beta$ -furoin oxime a light brown precipitate. The reaction was studied and the limit of detection was found to be  $0.32 \ \gamma$  Ni. The sensitivity of the reactions is  $2.10^{-5}$ . The reaction was studied in presence of other ions.—C.F.C.

The accurate determination of cobalt. II. Gravimetric methods and the phosphate method A. G. Foster and W. J. Williams (Anal. Chim. Acta, 1961, 24, Jan., 20–32) Some gravimetric methods are examined. The electrolytic method gave high results (about 1.4%), and the anthranilate method slightly high results (0.2–0.3%). A modified phosphate method, using a rapid spectrophotometric determination of residual Co, gave accurate results  $(\pm 0.1-0.2)$  and its use is recommended.

Gravimetric determination of molybdenum and its separation from other metals with Nenzoylphenylhydroxylamine S. K. Sinha and S. C. Shome (Anal. Chim. Acta., 1961, 24, Jan., 33–36) N-Benzoylphenylhydroxylamine is employed as a precipitate for the determination of Mo (VI). The precipitate can be weighed either directly or as MoO<sub>3</sub> after ignition. Mo can be determined in the presence of appreciable amounts of Fe (III), Co (II), Cu (II), Cr (VI), and V (V).—S.H.-S.

Determination of tervalent and quadrivalent manganese oxide in manganese and reduced manganese ores S. Watanabe (Nippon Kinzoku, 1960, 24, July, 409-413) Acetylacetone in presence of KI gives the tervalent salt in absence of ferric ion, which can be reduced with SnCl<sub>2</sub>.

The separation of vanadium and chromium from iron by extraction of ferric chloride with di-isopropyl ether G. A. Dean and J. F. Herringshaw (Analyst, 1961, 86, Feb., 106–110)  $\rm V^4$  and  $\rm Cr^3$  are separated from Fe $^9$  by a modified procedure. Di-isopropylether and 8–9 m HCl in the presence of  $\rm SO_2$  are used, this latter enables precautions to prevent formation of peroxides to be omitted and obviates the uncertainty normally found when  $\rm V^5$  is reduced with HCl. Reduction of Fe $^3$  by  $\rm SO_2$  is negligible and 99-98% of the Fe is extracted, with only traces of V and Cr.—c.v.

Liquid-liquid extraction of vanadium (V) with tributyl phosphate S. K. Majumdar and A. K. De (Anal. Chem., 1961, 33, Feb., 297—299) A rapid selective method of extraction is presented. V is treated with HCl (>5M) with 100%TBP; Cu², Ba², Bi³, Fe³, Co², Ni², Hg², Cr³, Th⁴, U⁵, Mo⁵, PO₄, and EDTA do not interfere. The effect of varying TBP concentration is also considered. The presence of NH₄Cl or MgCl₂ in the aqueous phase serves to exert a salting-out effect, leading to increased extraction of vanadyl salt.—c.v.

2,9-Dimethyl-1, 10-phenanthroline ('Neocuproine'), reagent for copper E. J. Newman and G. Peters (Organic Chemical Reagents, 1960, Monograph, No.50, pp.6) This reagent is very sensitive and selective, rapid, and simple; it is accurate to ±3%. Complete recovery of 40 μg Be², Zn², Cd², Hg², B<sub>4</sub>O<sub>γ</sub>, Tl, Th⁴, Sn², As³, SbO, SeO<sub>4</sub>², UO<sub>2</sub>², Fe², Fe(CN)<sub>6</sub>², Co², and Ni². Cyanide, 8 mg, did not interfere but ferrocyanide caused serious interference; 4 μg sulphide had a negligible effect but 40 μg showed a considerable reduction in the Cu recovered; low results were also obtained in the presence of pyridine. Full details of the procedure are given.—C. V.

An evaluation of the formate method for the simulfaneous polarographic determination of copper and lead in steel P. H. Scholes (Analyst, 1961, 36, Feb., 116–124) A linear-sweep cathode-ray polarograph is used and Cu can be determined with a standard deviation of 0.006% at the 0.1% level in samples containing >0.2%Mo. If smaller samples are taken a 2.0%Mo conen, can be present, but the accuracy is reduced. By introducing a slight modification, Cu can be determined in pure Fe down to 0.0001% after most of the Fe has been separated by solvent extraction. Sn, As, Ti, and Mo are reduced at peak potentials coincident with the Pb-reduction and thus the procedure is suitable for determining Pb in samples containing only residual amounts of these elements; interference by Mo is not serious if the conen. is not much in excess of that of Pb. In Pb-bearing steels (>0.05%Pb) a standard deviation of 0.008% is claimed. The method has been used with 30 samples ranging from high purity Fe to stainless steels.

The determination of lead in copper-base alloys and steel by atomic absorption spectrometry W. T. Elwell and J. A. F. Gidley (Anal. Chim., Acta., 1961, 24, Jan., 71 78) The principle of atomic absorption spectrophotometry has only recently been exploited as an analytical technique, and details are given of the development of a procedure for determining Pb in copper-base alloys and leaded steels. The method is simple, rapid, and provides results as accurate as those obtained by more time-consuming methods in current use.

Determination of samarium and other rare earths L. R. Pitwellt (Analyst, 1961, **36**, Feb., 137–140) The methods used and their limitations are discussed. With absorption spectrophotometry at 401–402 m $\mu$  (aqueous solution of chloride or perchlorate) the lower limits of reliable measurement is above 1 g Sm per l. With an Fe³ salt in HCl and an atm. of  $\rm H_2$  followed by titration of Fe² with dichromate solution, low results are obtained due to loss of Sm³ in the reaction with H $_2$ . If Sm sulphate is precipitated from an ethanolic solution in the

presence of Na amalgam, the pptn. is incomplete, and where it is pptd. as oxide or fluoride on Ce, Yt, or Al carriers there is a lack of spectral lines from overlapping lines of other rare earths while in polarographic determinations the half-wave potentials of the rare earths are close together. The most satisfactory method is precipitation of basic ceric nitrate but in the presence of Mg, a preliminary pptn. of Ce and Sm as hydroxides is essential to avoid the formation of the soluble ceric magnesium nitrate. Th is best separated by extraction as nitrate into tri-n-butyl phosphate and subsequent volatilization of Th as the tetrachloride. The experimentation is reported in some detail.—C. v.

Determination of boron content in ferroboron P. Répás and I. Sajo (Koh. Lapok, 1960, 93, Sept., 426) The method is a volumetric analysis of boron in ferroboron after removal of iron by electrolysis and of Al chemically.—P.K.

Precision of absorption spectrophotometric analysis S.-E. Dahlgren (*Tek. Tidakr.*, 1960, **90**, Oct. 14, 983–988) A theoretical treatment with an illustrated example.

Q correction in the spectra of the iron group G. Racah and Y. Shadmi (Phys. Rev., 1960, 119, July 1, 156-158).

Investigations on the spectrographic analysis of high alloy steels W. Diehl (Arch. Eisenh., 1961, 32, Jan., 11-18) Excitation problems in the spectrographic analysis of high-alloy steels using a grating spectrometer are examined critically, and sources of error assessed (24 refs)

New spectrophotometric method for molybdenum A. H. Black and J. D. Bonfiglio (Anal. Chem., 1961, 33, March, 431–432) This method is designed to give a rapid determination of Mo in low-alloy steels. Mo is separated from the bulk of the sample by Amberlite IR-120(H) after which an Mo-complex with phenyl-fluorone is formed; this is orange-red and obeys Beer's Law, and exhibits a maximum absorbence at 550 mm over a range of 0·33 to 1·67 mm Mo per ml giving excellent results with low-alloy steels with an Mo content 0·1–0·5%. Early work showed that the Mo was not completely removed from the column; complete removal was achieved by the addition of a small concentration of citric acid.—c.v.

Spectrophotometric determination of vanadium (V) with N-benzoyl-N-phenylhydroxylamine U. Priyadarshini and S. G. Tandon (Anal. Chem., 1961, 33, March, 435-438) This reagent has been found to be highly specific for V<sup>5</sup>; it forms a H<sub>2</sub>O-insoluble, deep-violet complex in strongly acidic solution and when extracted with CHCl<sub>3</sub> can be used for spectrophotometric determination of V and for its separation from other ions.—C. V.

Spectrographic determination of ferroalloys. IV. Determination of impurities in ferrosilicon Y. Yokovama (Sci. Rep. Res. Inst. Töhoku Univ., 1960, 12A, Dec., 511-517) A spectrographic method was studied to determine Mn, Cr, Ni, and Ti in Fe-Si with a quartz spectrograph of medium type. A stable discharge was obtained by exciting powdered ferrosilicon with a direct current arc. The favourable analytical line pair of each element to be determined was examined by using iron as internal standard. The calibration method described in the second report could also be applied to the analysis of ferrosilicon.—C.F.C.

Spectrographic determination of microamounts of calcium and magnesium in cast iron by the vorous-cup technique Y. Yokoyama (Sci. Rep. Res. Inst., Töhoku Univ., 1960, 12A, Dec., 525–531) A spectrochemical method was studied to determine simultaneously microamounts of Ca and Mg in east iron.—C.F.O.

Spectrochemical determination of small amounts of aluminium in steel Z. Takao and S. Mivosi (Tetsu-to-Hagane, 1916, 47, Feb., 145-152) The analysis described relates to concentrations ~0.005-0.1%. Combined use was made of a medium-sized quartz spectrograph and a grating spectrograph of the Ebert type using an ac intermittent arc. Austenitic grain size could be checked within a few hours of ingot making.—c.v.

Spectrophotometric determination of aluminium in the oresence of iron with eriochrome cyanine-R. Tests with a decolorized reagent M. Barrachina Gómez, L. Gasco Sanchez, and

R. Fernandez Cellini (Anal. Real Soc. Espan. Fis. Quim., 1960, 56(B), Nov., 861–868) [In Spanish] The behaviour of the extinction coefficient of aqueous solutions of eriochrome cyanine R has been studied as part of the search for a means of rapidly determining Al in boron steels. At pH 5–6 the solutions decolour, according to an exponential law, on spontaneous transformation of the reagent to a more stable form, but these continue to react with the Al and make more suitable reagents for spectrophotometric purposes (12 refs).

Spectrographic determination of microamounts of cerium, lanthanum, neodynium and praseodymium in iron and steel Y. Yokoyama (Sci. Rep. Res. Inst., Töhoku Univ., 1960, 12A, Dec., 518-524) A spectrographic method was studied to determine microamounts of rare earths in iron and steel with a quartz spectrograph of medium type. Rare earths were separated by precipitating them as fluorides from an acid sample solution, and the fluorides were converted into chlorides, which were then excited on a copper electrode by an intermittent arc.—C.F.C.

Neutron activation analysis and its use in steel analysis W. Riesner and H. Schneider (Arch. Eisenh., 1961, 32, Jan., 31-38) Examination of the use of this technique in steel analysis shows that it is inferior to more usual methods of determination, except in exceptional cases. Details of the investigation are given (24 refs).

The determination of tungsten in high alloy steels by isotope dilution (Rec. Trav. Chim. Pays Bas, 1960, 79, June, 557-566) [In French] An isotope dilution procedure using 185W has been developed for the determination of W in high alloy steels. W is determined spectrophotometrically with hydroquinone in sulphuric acid after homogeneous precipitation from a nitric acid-hydrogen peroxide solution. The method was successfully tested on a number of NBS high-alloy steels to which varying amounts of Ta and Ti were added

The use of X-ray fluorescence spectrographic analysis in the iron and steel industry H.-J. Kopineck and P. Schmitt (Arch. Eisenh., 1961, 32, Jan., 19-29) The suitability of this method for analysing iron and steelworks materials is discussed, and it is shown that it can be used for the analysis of ores, slags, and refractories, but is only suitable in special cases for the analysis of steel. The examination of OH slags is given as an example, with particular reference to the rapid determination of basicity. Other examples are given (22 refs).

Determination of minor constituents in lowalloy steels by X-ray spectroscopy R. E. Michaelis, R. Alvarez, and B. A. Kilday (J. Res. NBS, Eng. Instr., 1961, 656, Jan., March, 71–76) X-ray spectroscopy was used to analyse low-alloy steel. Detection limits and interference was studied for the following elements: Ag, As, Co, Cr, Cu, Ge, Mn, Mo, Nb, Ni, Pb, S, Se, Si, Sn, Ta, Ti, V, W, and Zr. In most cases the detection limit is <0.01% which is sufficient for control analysis. Interference or interelement effects were not found to be serious but do occur, e.g. Zr interferes with Mo. The application of the NBS standard samples to these determinations is discussed.—c.v.

X-Ray analyser benefits foundry three ways H. Kistner and A. Braun (Steel, 1960, 147, Oct. 17, 140) The operation of an X-ray spectrometer, acting as a three-dimensional diffraction grating and cutting analyses formerly requiring 8 h to less than 20 min, is briefly described and the results evaluated.—s.H.-S.

Apparent loss of iron during fusion of silicate materials with sodium hydroxide in nickel crucibles H. Bennett, R. P. Eardley, and I. Thwaites (Analyst, 1961, 86, Feb., 135–136) Rapid methods for the determination of aluminosilicates and materials of high Si content were studied and it was found that Fe was retianed by the Ni crucible in which the sample was decomposed. The experimentation if discussed and it is suggested that some of the Fe is reduced and forms an Ni-alloy but the peculiarity of the problem lies in the constancy of the ratio of loss to the total Fe-content of the sample.—c.v.

A special adaptation of the Volhard method for the analysis of manganese oxide ores  $V,\ L.$ 

Garik and L. M. Silber (Anal. Chem., 1961, 33, Feb., 319–320) An analytical method of determining the Mn content of certain compounds in terms of Mn² and Mn⁴ is presented. The oxides most frequently found are MnO, MnO₂, Mn₂O₃, and Mn₃O₄. MnO can be leached out with warm dilute H₂SO₄, Mn will pass into Mn² and Mn⁴, and MnO can be determined by various standard procedures. Under the same conditions, MnO₂ will not be affected and the ratio can be determined by the difference between the total Mn content and the MnO in the sample. This can also be determined by standard procedures. Certain difficulties associated with the Volhard procedure are discussed. Details of the test are given and tis found that it is satisfactory as regards precision (±0.25%).—c.v.

Fractional determination of metallic manganese and manganese monoxide in reduced manganese ores S. Watanabe (Nippon Kinzoku, 1960, 24, (4), 217–221) [In Japanese] The difficulty of bringing the metallic Mn into soln. with the minimum amount of MnO is best dealt with by using methanol containing HgCl<sub>2</sub> at 70°C for 1 h (relative amounts given).

Fractional determination of ferro-manganese and manganese monoxide in reduced manganese ores S. Watanabe (Nippon Kinzoku, 1960, 24, (4), 221-225) [In Japanese] Metallic Mn is best determined without other constituents interfering by using methanol containing CuCl<sub>2</sub> and Na<sub>2</sub>CO<sub>3</sub> at 40°C for 1 h (relative amounts given).—K.E.J.

Separation and determination of oxide inclusions in plain carbon steel with a methanolic bromine solution. I. Separation and determination of oxide inclusions in plain carbon steel with a methanolic bromine solution. II. Comparison of dissolution of iron with methanolic bromine and iodine Y. Okura (Nippon Kinzoku, 1960, 24, (4), 237–241; 241–245) [In Japanese] I. For a steel containing <0.5%C, a new procedure is based on soln. in 10% methanolic bromine at room temp. It is simpler and quicker than previous methods, and nitrides of Fe and Mn and sulphides of Fe are all dissolved (62 refs). II. Advantages over the methanolic iodine method are described.

Determination of the available oxygen in manganese and reduced manganese ores Watanabe (Nippon Kinzoku, 1960, 24, July, 405-409) [In Japanese] Methods of obtaining correct results from both the oxalate and ferrous sulphate methods are given.

The electron probe X-ray microanalyzer, an important microanalytical tool R. Kiessling (Jernkont. Ann., 1960, 144, (11), 847–854) The principle, correction factors, and applications of the instrument are described, with particular reference to the 'Cameca' design used at the Swedish Institute for Metal Research (25 refs).

Emission spectrometric determination of oxygen, nitrogen and hydrogen in metals V. A. Fassel (ISI Special Report (68), 1960, 103–120) These techniques are based on melting the metal and extracting the gaseous elements with a de carbon arc discharge in pure A. The emission spectra of the extracted gases are excited with the same arc discharge. Chemical reduction reactions play a primary role in converting the combined oxides, nitrides, and hydrides into CO,  $N_2$ , and  $H_2$ .—c.v.

Experiences with automatically recording, spectral analysis apparatus and an X-ray diffractometer in a foundry laboratory H. Zeuner (Giesserei, 1960, Dec. 29, 47, 747-753) The use of a fluorspar vacuum polychromator, a medium prism spectrometer and an X-ray vacuum diffractometer are discussed from the point of view of their application to analysis in a foundry laboratory.—R.P.

Foundry control of cast iron with a vacuum direct-reading spectrometer E. L. Roth, G. P. Antonic, and A. Goldblatt (Spectr. News, 1961, 14, Jan.—Feb.—March, 1-4) The operation of a vacuum direct-reading spectrometer (Quantovac) installed at Motor Castings Company's plant at Milwaukee, Wisconsin, with an account of the initial investigation for the selection of suitable source parameters and a comparison of the Quantovac and Combustion Carbon determinations is presented.—s. H. S.

The pyrolytic determination of fluorine in fluxes and electrode coatings F. Eliáš (Zváranie,

1961, 10, (4), 104-106) [In Slovak] A rapid alkalimetric method developed by the author

is described.-P.F.

Rapid complexometric determination of phosphorus in coal A. C. Bhattacharyya, B. P Bhaduri, and N. G. Banerjee (Analyst, 1961, 86, March, 195-198) A method is presented in which phosphorus is extracted from coal ash by treatment with perchloric acid and then pre cipitated as ammonium magnesium phosphate, magnesium in the precipitate being subsequently determined by titration with EDTA. The maximum mean duration of replicate determinations was 0.003%, but was generally less than 0.0015%, being similar to that of the British Standard method. By this simple and rapid procedure one worker can analyse five samples per diem .- s. H.-s.

### INDUSTRIAL APPLICATIONS AND USES

Development and importance of heat-resisting steels for boiler construction  $W.\ Ruttmann$ (Mitt. Ver. Grosskessel., 1960, (69), Dec., 356–365) A review of testing methods at elevated temps, and of the development and applications of heat-resisting steels, with reference to the literature (56 refs).

The relationship between properties of the material and behaviour in service of cylinder liners and piston rings W. Rauterkus (Gesserei, 1961, 48, April 20, 210-222) The distribution scatter of behaviour in service of cylinder liners and piston rings in function of variation of material properties-composition, structure, and preceding treatment—was studied and the effect of the various factors was discussed. The importance of careful choice of materials according to properties affecting varied behaviour in service is demonstrated.—M.L.

Chromium steels in refinery service R. W. Manuel, F. K. Zerbe, and K. G. Carroll (Met. Prog., 1960, 78, Nov., 124, 126, 128, 130, 132, 134, 136) A discussion (correspondence) on an article by Scheil 'Chromium steels remain tough after eight years at high temp. (ibid., 1960, April), together with Scheil's replies

The status of research and development for high strength aircraft steels E. M. Kennedy jun. (PB 171077, Rept. for 1956-1959 on Metallic Materials, 1960, July, pp. 36; WADC Technical Note, 59-326, from US Res. Rep., 1961, 35, Jan. 13, 92) Steels with tensile strengths in excess of 260 000 psi are being developed

Design information on 17-7 PH stainless steel for aircraft and missiles R. J. Favor, O. L. Deel, and W. P. Achbach (PB 151096, 1960, Sept., pp. 37; DMIC rept. 137; from US Res. Rep., 1961, 35, Jan. 13, 92) Elevated temp. design curves for short-time ultimate tensile strength, tensile yield strength, compressive yield strength, ultimate shear strength, bearing ultimate strength, and bearing yield strength are presented. These curves have been based on a number of published and un--published reports and papers. Data are summarized in Appendix A in a format recom-mended for MIL-HDBK-5 (superseding ANC-5), Strength of Metal Aircraft Elements. Appendix B contains summary plots substantiating data from which designs allowable strengths were derived .- C.F.C

Problems encountered in the use of high-strength steels in structures J. Fuchs (Zvar. Sbornik, 1961, 10, (1), 89-99) [In Czech] Economic and engineering problems arising in the application of recently developed high strength steels are discussed. Constancy of chemical composition must be maintained, and the comparatively low fatigue limit and notch sensitivity must be taken into account in welding .- P. F.

Principles governing the use of stainless steel in the chamical processing industry K. H. Brakstad (Tek. Uke., 1961, 108, Jan. 19, 65-66) A brief review of the economics and range of application of stainless steel in the chemical industry, with special reference to 18-8 steel.

A stainless steel for standard weights S. J. Rosenberg and T. P. Royston (Mat. Res. Stand., Bull., ASTM, 1961, 1, Jan., 21-22) Data for two stainless steels suggested as suitable materials for standard weights, designated ;SW-12 and SW-13, are presented, with tables

of composition and of permeability and density, and with representative photomicro-graphs.—s. H.-s.

### HISTORICAL

The methods of manufacturing iron articles in Poland at the beginning of the Middle Ages J. Piaskowski (Met. Corr. Ind., 1960, May, 206-216) [In French] The chemical composition and the methods of manufacture of knives, tools, and weapons made from iron, carburized iron, and/or steel are described.

The old blast furnace plant in Ujmassa, Hungary B. Simon (Koh. Lapok, 1961, 94, Feb., 81-85) The author describes the layout and operation of the 150 year old blast-furnace plant in Ujmassa, Hungary, that was the predecessor of the Lenin Iron and Steel Works in Diosgyör .- P. K

50 years since the foundation of the Technical Society for ferrous metallurgy D. A. Smolyarenko (Metallurg., 1960, (11), 1-2) [In Russian] This Society was founded in St Petersburg in 1910, and the article is a condensed record of its activity.

### ECONOMICS AND STATISTICS

'Looking ahead in steel' M. N. Dastur (Iron Steel Rev., 1961, 4, Feb., 19-27) The necessity for co-ordination and development of the steel industry in India is briefly discussed. The position of the coal, limestone, and manganese reserves require careful study.

The Chinese Iron and Steel Industry, during 1958 B. V. Lenskii (Byulletin tekhniko-ekonomicheskoi informatsii, 1959, (6), 73–76; from LLU Transl. Bull., 1959, Nov., 7–13) A discussion of output, products, new plant, and

other developments.

Review of B. S. Sharapan's book 'Analysis of the economic activity of metallurgical works' M. A. Barun (Stal', 1961, (4), 365-366) Considerable criticism is directed against much of the book

Effects of rolled steel requirements and raw Effects of rolled steel requirements and raw materials supply on the American and German steel industries E. Kemna (Iron Steel Eng., 1960, 37, Dec., 97–102) The different conditions in Germany, larger numbers of products and specifications and geographical conditions, etc., are compared with those of USA and their offerts aggregated. their effects assessed.

Norm of production or the actual cost of raw materials W. Woznica (Hutnik, 1961, 28, (2), 49-51) Order no.71, dated 27 April 1960 issued by the Polish Ministry for Heavy Industry made the payment of production bonus dependent on the cost of production as well. The author discusses the need for replacing the old norms for allowed production losses by the analysis of the actual cost since often better yield could be obtained by using more expensive raw materials. An average total cost (1960) of 1 t of electric furnace steel (5373 zloty per t) was made up of following items: metals charged: 73·3%, production cost: 22·8%, rejects: 1%, overheads: 2·9%, at a yield of

# MISCELLANEOUS

Automation in the metallurgical industry V. Ya. Atlaev (Metallurg., 1960, (11), 34-36) [In Russian] A report on the Congress of the International Federation for automatic control, held in Moscow between the 27 June and 2 July 1960 with a brief mention of the papers read by the BISRA, Russian, Federal German, and Chinese delegates.

The automation of metallurgical works is the principal task of the day K. P. Kostenetskii (Metallurg., 1960, (11), 3-5) [In Russian] General consideration of the problems involved having regard to a smooth operation, constructional problems, transport, general control of production, general principles of the layout, and the efficiency of an automated overall production control. A suggested scheme is appended as a basis of discussion.

Data processing as related to the steel plant H. R. Berke (Blast Furn. Steel Plant, 1960, 48, Dec., 1262-1264) The functions of digital computing systems, their advantages, and difficulties in their application are summarized.

Application of digital control computers to

steel industry process control R. W. Kirkland (Iron Steel Eng., 1960, **37**, Dec., 134–147) The reasons for the use of on-line digital computers are reviewed, their characteristics considered, and some applications described

Computers used for analyzing production indices in ferrous metallurgy S. M. Filippov (Metallurg., 1960, (11), 36–38) [In Russian] Suggestions are outlined by the GOSPLAN as to the use of computers for solving such problems as the selection of optimum components, distribution of the labour among the different types of equipment, the best methods for using materials with the smallest amount of waste,

Ion exchange H. F. Walton (Ann. Rev. Phys. Chem., 1959, 123-144) A review containing 163 references relating to inorganic and organic ion exchangers, the thermodynamic aspects, ion-exchange membranes, and separations attained by this method. Diffusion and kinetic studies are also reported together with the catalytic effects that have been noted.—c.v.

Factories Acts up to date N. H. Jones (Safety, 1961, (12), 22-23) A review of the present position of the Iron and Steel Industry in relation to the Act, by the former HM
Deputy Chief Inspector of Factories, now Safety Consultant, United Steel Companies.

All fingers and thumbs D. Thomas (Safety, 1961, (12), 4-8) The results of a research project to find the best gloves for handling finished steel sheets at Port Talbot plant of SCOW, with striking reduction in hand accident rate after 3 months' test, is reported.—s. H.-s.

Safe on the blast E. A. Cotterill (Safety, 1961,

(12), 16-21) A brief report on the reduced accident rate resulting from a year's test of a project for retraining operatives in the Blast Furnace Dept. of Park Gate Iron and Steel Co.

is presented.—s. H.-s.

The effect of noise on steel workers G. Jansen (Stahl Eisen, 1961, 81, Feb. 16, 217–220) The effect of noise on steelworkers was studied. Besides damaging the hearing, noise has a particularly bad effect on the vegetative reactions of the human organism. The vegetative disturbance is far greater than previ-ously assumed and is markedly produced by broad-band noise, whose effects can be detected in human beings both during resting periods and during working.—T.G.

### **BOOK NOTICES**

ADVISORY GROUP ON ELECTRON TUBES. 'Proceedings of the Fourth National Conference on Tube Techniques'.  $11 \times 8\frac{1}{2}$  in, v+270. Illustrated. 1959, New York: New York Univer-

The Advisory Group which sponsored this Conference, held in September 1958, is an agency of the American Assistant Secretary of Defense and was set up to promote the research and development programme in the field of electron tubes and semiconductor devices. A total of 46 papers are presented (including five in abstract form). Most of the papers deal with specialist applications and techniques and will be of interest mainly to those working in the field of electronics. Two papers of wider significance (abstracted in the Journal) concern, first, microwave vacuum tube techniques in Europe (with an outstanding list of references) and, secondly, the production of copper-base and copper-cored aluminium clad steel strip and its application as a new material for tube anodes

AMERICAN INSTITUTE OF ELECTRICAL ENGIN-EERS. 'Proceedings of the 5th Conference on Magnetism and Magnetic Materials'.  $10\frac{1}{2} \times 8$ in, pp.vii + 420. Illustrated. 1960, New York, London: McGraw Hill Book Company. (Price £3 17s. 6d.)

'Berichte der Arbeitsgemeinschaft Ferromagnetismus 1959'. 11½ × 8½in, pp.270. Illustrated. 1960, Düsseldorf: Verlag Stahleisen m.b.H.

(Price DM.40.--)

Both of these books are proceedings of recent conferences dealing with various aspects of research and development on magnetic materials and devices. The American conference is now an annual event sponsored by the American Institute of Electrical

Engineers. It has a world-wide reputation and the conference proceedings provide an and the conference proceedings provide an up-to-the-minute record on the latest researches, particularly in the USA. The report under review deals with the fifth conference held at Detroit in November 1959. It is divided into fifteen sections covering almost the whole subject of ferromagnetism starting from the theoretical standpoint at one end, passing on to the properties of magnetic materials, and finally to their applications, for example, in com puter storage devices and in non-reciprocal devices at microwave frequencies. The com-pleteness of the treatment varies considerably from paper to paper but the general standard is high. It has now become the custom to publish the full proceedings of this conference as a supplementary volume to the Journal of Applied Physics; it is published most commendably only some six months after the date of the conference. This supplementary volume can be pur-chased at approximately one-sixth of the cost of the present book and it is doubtful whether the excellent binding warrants the large extra cost.

The second book deals with a conference held by the German Working Party on Ferromagnetism in Berlin in October 1959. The scope of this conference is considerably more restricted than that held by the AIEE and deals largely with the properties and applications of magnetic metals and alloys. The common ground shared by the two conferences is the subject of magnetic films which promise to be of vital importance as quick access memory stores in the next generation of ultra-high-speed computers. The subject matter of the Berlin conference is not available in any other form and considerable thought has been given to the reproduction in order to keep the cost low. It appears unfortunate that this conference It appears unfortunate that this conference does not have greater publicity so that it could more adequately represent the considerable volume of work being carried out in Europe on the subject of magnetism.

Association of Tar Distillers. 'Coal Tar Fuels'. 2nd ed. 8½×5½in, pp.vi+112. 1961, London: The Association. (Price £1 1s.)

The first edition of this monograph was published in 1944. It is now virtually rewritten and deals in brief but competent style with post-war developments in liquid fuel usage and the preparation and applica-tion of coal tar fuels. The themes treated are source and methods of production, chemical composition and properties, combustion and composition and properties, combustion and flame, the design of equipment for storage and handling, burners and equipment, and applications. A short list of books and an index completes the volume.

Banks, O. 'The Attitudes of Steelworkers to Technical Change'. 8½×5½in, pp.viii+152. 1960, Liverpool: Liverpool University Press. (Price 41.5%)

(Price £1 5s.)

(Ring 17 3s.) Brody, D. 'Steelworkers in America. The Non-union Era'. 7\frac{3}{4} \times 5\frac{1}{4} in, pp.303. 1960, Cam-bridge (Mass.): Harvard University Press. (Price £2)

These two books, each of which has a university imprint, are vastly different in style, approach, method of investigation, historical period and subject matter, and much else. Nevertheless, they have one thing in common: close attention to the response of workers in the steel industry to technological advance

The British book is an intensive study of some aspects of the research project pre-viously reported in Technical Change and Industrial Relations by W. H. Scott et al. (reviewed JISI Sept., 1958) which dealt with the introduction of a continuous strip mill, the replacement of two old melting shops by a larger modern one, and the negotiations and problems arising from these changes which began about 1951. Dr Bank's work is the British contribution to similar studies that have been undertaken in seven European countries. The second book by Mr Brody covers the 1890s to 1929, a turbulent period in the history of labour relations in the American iron and steel

industry, full of such violent storms as the steel strike of 1919. It is essentially a history of the steelworkers themselves and of how labour organizations, once strong in the industry, were weakened during a period of rapid technological advance. The contrast with British experience as shown in the first book, admittedly of one works only, and of

an entirely different period, could hardly be more marked.—M. L. Pearl.

Bleinner, G. et al. (Editors). 'Handbook der Regelungstechnik'. 9½ × 6½in, pp.vii+1516.

Illustrated. 1961, Berlin: Springer-Verlag.

(Price DM.248.-

The object of the publishers of this hand-book was to collect in one volume the enormous amount of data dealing with the application of various types of controllers application of various types of controllers to a wide range of industrial processes that is at present distributed amongst a large number of technical publications. They called in the assistance of 55 specialist contributors of whom 31 are employees of Siemens-Schuckertwerke AG and 16 of Siemens & Halske AG, and so the range covered is very wide; indeed the only controllers that are not covered are those used trollers that are not covered are those used in nuclear plants and in connexion with jetdriven aeroplanes. Devices for automatic take-off and landing of aircraft are, howeverdescribed. Controllers used in the iron and steel industry appear in ten of the chapters of part V. Chapters 36–41 are devoted to controllers used for the different operations entailed in mining and raising the ore and for converting it into finished steel. Chapter 41 which has been written by Drs Bretthauer and Stepken of Siemens-Schuckertwerke AG, Erlangen, is particularly comprehensive, and deals with the general control of cross-country hot mills and continuous hot-mills and of cold rolling reversal mills and tandem cold-rolling mills and, *inter alia*, describes loop controllers. In the final section the control of rotary slitting machines is described.

Chapter 46 is devoted to foundry plant and describes apparatus used for the control of hot-blast furnaces and of drying ovens. Chapter 47 is mainly concerned with the temperature controllers whilst chapter 48 deals with the controllers required for electrical welding plants. Chapter 49 deals with the control of machine tools. Chapter 50 of part V may at first appear somewhat out of place because it deals with the control of paper making, textile, india-rubber pro cessing and printing machines, but many of the devices described could be applied to, say, cold rolling mills and/or wire drawing plants and the section is well worth reading.

To anyone with only an elementary know-ledge of the subject this handbook will be very easy to follow. Most of the diagrams are self-explanatory and an understanding of the text does not call for a profound know-ledge of German. There are more than 1200 well chosen references and the book conwell chosen references and the book con-cludes with a name index and a particularly comprehensive subject index. The book is well produced and worth its high price. —J. F. KAYSER

THE BRITISH CERAMIC RESEARCH ASSOCIATION. 'The A.T. Green Book'.  $9\frac{3}{4} \times 6\frac{1}{4}$ in, pp.x+309. Illustrated. 1960, Stoke-on-

Trent: The Association.

It was an excellent idea to pay tribute to Dr A. T. Green's long association with the ceramic industry by producing a 'fest-schrift' in his honour written by his col-leagues of the British Ceramic Research Association. The contributors do justice to the theme and cover the whole range of ceramics from the origins and development of the association to the principles of furnace design. The last contribution, together with other articles of interest to the steel industry, are abstracted in the Journal.

Centre D'Information du Cobalt. 'Cobalt Monograph'. 9×6in, pp.xv+515. Illustrated. 1960, Brussels: M. Weissenbruch S.A. (Price B.F. 750).

Young, R. S. (Editor). 'Cobalt. Its Chemistry,

Metallurgy and Uses'. A.C.S. Monograph Series 149. 9×6in, pp.vii+424. Illustrated. 1960, New York, London: Reinhold Publish-

ing Corp., Chapman & Hall Ltd (Price £6) It is sometimes considered unfortunate when two works on the same subject appear at the same time. In the present case it is advantageous since these books supplement one another. The special contribution of the first work, which was produced in collaboration with the staff of Battelle Memorial Institute on behalf of the Cobalt Information Center, is in the number and clarity of the tables, graphs and microphotographs and it can be highly recommended on these grounds. It contains a bibliography of 1224 references. The treatment is extremely thorough and the subjects covered include history, mining, extractive metallurgy, economics, physical and mechanical properties, chemistry, alloy systems, magnetic materials, tool and die steels, cemented carbides,

coatings, glass and ceramics, industrial

applications, agriculture and medical as-

pects.

The second work replaces Monograph No.108 in the American Chemical Society's series and contains six specialized chapters; co-ordination compounds of cobalt; phase diagrams for cobalt; magnetic, electrical and electronic applications; cobalt alloys in hightemperature, high strength and high service; catalytic behaviour of cobalt; and radio-active cobalt. There are also chapters relat-ing to history, occurrence, extractive metallurgy, electroplating, biology and biochemistry, and analysis, and a bibliography of some 1 400 references.—C. Voge Column Research Council. 'Guide to Design

Criteria for Metal Compression Members',  $10\frac{3}{4} \times 8\frac{1}{4}$ in, pp.xviii+93. Illustrated. 1960, Ann Arbor: The Council. (Price \$5.00).

This is a concise summary of design cri-

teria on metal compression members in buildings and bridges. It is based on research supported and undertaken by some of the leading organisations in the United States of America; while it does not attempt to supplement existing specifications, it offers guidance towards improving them. Con-struction metals under ASTM specifications are covered, including the new ASTM 36 structural carbon steel. A second edition is promised which will include such subjects as

promised which will include such subjects as the design of plate in girder stiffeners and the local buckling of plate girder webs.

FOX, SAMUEL & CO. LTD. 'Alloy Steels', 11×8½ in, loose leaf, 250pp. Illustrated. 1961, Sheffield: The Company. (Price £2 2s.)

CHAMBRE SYNDICALE DES PRODUCTEURS D'ACIERS FINS ET SPECIAUX, 'Manuel Technique. Acier Inoxydable'. Annuaire 1959-29 ed. 9×6in, pp.384. Illustrated. 1959-1960, Paris: SEMAS (Price NF 30.00).

ASSOCIAZIONE ITALIANA DI METALLURGIA

ASSOCIAZIONE ITALIANA DI METALLURGIA.

'Atlante Metallografico di Acciai Unificati'.

9½ × 6½in, loose leaf. pp.iii+108 plates + 23.

Illustrated. 1960, Milan: AIM.

These three volumes in English, French

and Italian respectively all deal in different

ways with the properties and compositions of a wide variety of steels.

The first book, the work of a well-known British company, consists essentially of data sheets on 21 of the more important low alloy steels of the En series specified in BS 970. Other high alloy steels of the corrosion and heat resisting types are not given data sheets but are only listed with a statement that data sheets for such steels may be obtained from the company on request. The data sheets give typical mechanical properties at room temperatures as affected by both heattreatment and section size as well as information of some of the more useful physical properties. These tables would be enhanced by including mechanical test data at low and elevated temperatures of shear and fatigue strength and of such physical properties as Young's and shear moduli, Poisson's ratio, specific heat and thermal conductivity. A useful feature of the data sheets is the inclusion of Jominy curves and both isothermal and continuous cooling diagrams. This book will be welcomed by many alloy steel users.

The second book on corrosion and heat resisting steels is issued by a group of French manufacturers of special steels and contains useful information on the fabrication, heattreatment, hot working, machinability, weldability, etc., of a wide range of steels, including modern steels for jet engines. Typical mechanical and physical properties are given for each steel and high-temperature and creep data for the heat resisting steels. The publication would be improved by a better presentation, it being difficult for one not familiar with the French standard designations to find the particular steel he is interested in. An annoying feature of the publication is the overprinting of the text with illustrations of typical applications and the book would be much more handy if the numerous pages of advertisements were dispensed with. This second edition is issued with a correction insert of seven pages

The third book, a metallographical atlas produced by the leading metallurgical society in Italy, is a well printed reference book giving typical photomicrographs of a wide variety of steels in different conditions of heat-treatment. Full information regarding the composition, section size, heat-treatment, etching medium and constituents revealed in the microstructure are given alongside each photomicrograph, which are reproduced in magnifications of 100 to 1500 according to the detail it is desired to illustrate. This book will prove a useful addition to any metallographist's library and though it is in Italian, a knowledge of this language is not essential since a very useful list of equivalent terms in French, English, German and Spanish is provided (although Nitride would have been a better translation

of Azoturo than Azide).—J. WOOLMAN.
GACKENBACH, R. E. 'Materials Selection for Process Plants'. 9×6in, pp.x+318. Illustrated. 1960, New York, London: Reinhold Publishing Corp., Chapman & Hall Ltd

(Price £3 8s.)

The author is a chemical plant corrosion engineer, and the book is about materials for tanks, piping systems, heat exchangers, valves, pumps and in general, structures and fittings for process plants. Nevertheless, the engineer who makes aeroplanes, automobiles or even spring clips will find a detailed experience of choosing the right material. The author discusses corrosion resisting and mechanical properties, often with references to the effect of high temperatures, fabricating characteristics, and costs. The first 43 pages are concerned with a very helpful discussion of corrosion, theory and effects, and protection including design techniques. A wide variety of metals is dealt with and there is a valuable chapter on stainless steels. Joining methods and heat-treatments are described critically. Included in the materials are brick construction and the newest cements, plastics, rubbers and elastomers, paints and coatings. Two glossaries are appended of terms used in studies of corrosion and metallurgy. Each chapter is one of the very best summaries yet offered to the engineer and metallurgist to help in selecting the best material in terms of manufacture, service and cost

GORBUNOV, N. S. 'Diffuse Coatings on Iron and Steel'. Translated by S. Friedman, A. Artman and Y. Halprin from the Russian. 9½×7in, pp.165. Illustrated. 1960, Jerusalem: Israel Program for Scientific Translations, (Price, Price, 1981).

lations. (Price £2 10s.)

The formation of binary or complex surface alloy layers by solid diffusion in order to impart special properties is no new concept. Commercial processes such as Sherardising, Calorising and Chromising, are regularly applied to steel when it is desired to enrich the surface in zinc, aluminium and chromium respectively. Possibilities in regard to thermal diffusion are, however, by no means confined to steels or other ferrous-base metals and, whilst there is a rapidly ex-panding need for less well known combina-tions, the principles involved are generally the same as when iron constitutes the base metal, as in the studies described in the present book, published in Moscow in 1958 'Diffusionnye pokrytiya na zheleze i stali' It has been translated as part of a series

commissioned in Israel by the National Science Foundation of Washington and the US Department of Commerce.

The author first discusses the general theory of diffusion and the relationships between atomic diameter, solubility and temperature. Techniques involving liquids, gaseous compounds and metallic vapours as carriers are then described, as is also the application of spectrographic and radio-active tracer methods and X-ray and electron probe analysis to the study of diffusion zones. Subsequent chapters are devoted to each group of the periodic table, only those elements forming useful solid solutions being considered in detail. Elements of the eighth group are not referred to in the survey and, as these include nickel, cobalt and platinum, this omission is rather surprising. The diffusion experiments described are all of the laboratory type, and there is hardly any mention of the important industrial protection. tion processes based on diffusion. Many of the photomicrographs are not very convincing, but this is probably largely due to poor reproduction.

Although unlikely to appeal to the general reader, the book will be welcomed by scientists and technologists faced with surface diffusion problems and anxious to refer to

recent work carried out and published in Russia.—M. L. Becker.

Hearmon, R. F. S. 'An introduction to applied anisotropic elasticity', 9×6in, pp.ix+136. Illustrated. 1961, Oxford: University Press.

(Price £1 15s.)

The aim of this book is to collect information on the properties of anisotropic elastic solids, especially single crystals as well as sheet material and polycrystalline aggregates. It should be particularly interesting to research workers in crystallography, seismology and non-destructive testing. The first two chapters are on fundamentals and deal with the tensor notation applied to the generalized form of Hooke's law, the expressions for the rotated elastic constants as functions of orientation for the most general anisotropic elastic body and crystal symmetry. Reference is made to the various notations used in the classification of the 32 crystal classes. Methods of measurement of elastic constants are reviewed and some values for the orthorhombic, trigonal, hexagonal and cubic systems are given. Reference is made to the relation between the elastic constants of single crystals and polycrystalline aggregates and expressions are derived for the average values of the elastic constants and compliances which represent the conditions of uniform strain and uniform stress throughout the assemblage respectively. Wave propagation is discussed in much detail and research workers in ultrasonics will find this section very helpful especially as the exact theory for anisotropic bodies has only been formulated in recent years. Other topics discussed include simple stress systems such as hydrostatic pressure and torsion and the bending and twisting of anisotropic plates and many problems of vibrations

-M. F. MARKHAM Higgins, R. A. 'Engineering Metallurgy. Part 2. Metallurgical Process Technology'.  $8\frac{1}{2} \times 5\frac{1}{2}$  in, pp.xi+404. Illustrated. 1960, London: English Universities Press Ltd. (Price

£1 58)

RAWLINGS, R. 'Practical Physical Metallurgy  $8\frac{1}{2} \times 5\frac{1}{2}$ in, pp.vii+159. Illustrated. 1961, London: Butterworths Ltd. (Price £1 10s.) These new text books, on technological

and physical metallurgy respectively, should meet a real need in the many technical colleges where the subject is taught at

elementary and advanced levels.

In 1957, Mr Higgins produced Part 1 of this series, 'Applied Physical Metallurgy' and references back to it are made in this complementary book on the practice of shaping and treating metals. A feature is the wide range of the survey and the critical detail. All the usual melting and casting processes are reviewed including shell moulding and investment casting but not the recent vacuum melting and casting of steels and nickel alloys. Other subjects in the 20 chapters are forging, including die design; heat-treatments with details of materials and equipment; extrusions omitting high temperature work with glass lubricant; cold working processes including stretch-forming and rubber pressing; bright annealing; powder metallurgy and the joining of metal-Operations and tools are clearly illustrated. Brief references to nuclear energy and transistors are made in a review of new metals. The author should reconsider fig. 7.8 on hot vorking and recrystallisation. Students are fortunate to have this book available

The few laboratory manuals for physical metallurgy are mostly of American origin. There should be a welcome for Rawlings' book containing 50 experiments which include mechanical testing, the determination of transformation temperatures by thermal and dilatometric methods, the heat-treatment of steels including hardenability and strain ageing, the quench ageing of alloys of aluminium, work hardness and recrystalliza-tion and a study of diffusion. The experi-mental procedure is carefully set out to show the metallurgical principles which decide the accurate measurement of propreties. There is a pleasing modernity about the work. The real disappointment is the brevity of the promised 'adequate and sufficient theory' to pass level B.Sc. Space could have been found for more text by reducing the considerable size of many line diagrams. For the technical college the book should be retitled 'Advanced Practical Physical Metallurgy', for the new student will not find instruction on the preparation and interpretation of microstructures of pure metals and common industrial alloys. The only microstructures are six depicted on the loose cover and again, with much less success, inside, of 'partially (isothermally) transformed eutectoid steel'. They have the merit of indicating what may be expected in the book.—J. W. Jones.

THE INSTITUTE OF PHYSICS, 'Laboratory and Workshop Notes', 1956–1958,  $8\frac{1}{2} \times 5\frac{1}{2}$ in, pp. xii+218, Illustrated, 1960, London: Edward

Arnold (Publishers) Ltd. (Price £2).

'Selected Papers on Stress Analysis'. 10\(^2\)\(\frac{1}{4}\)\times 8in,
pp.113. Illustrated. 1961, London, New
York: Chapman & Hall Ltd., Reinhold
Publishing Corp. (Price £2 10s.)

Dr Ruth Lang in 'Laboratory and Workshop Notes' brings together, as she has done in five volumes since 1949, a selection of valuable notes previously printed in the 'Journal of Scientific Instruments' and issued here with a useful subject index. 'Selected Papers on Stress Analysis' is the report of a conference held in Delft in April 1959, and organised by The Institute of Physics in conjunction with The Netherlands Institut TNO. A total of 51 papers was discussed at the conference, the main topics being methods of stress analysis and their appli-cation. A selection of 18 papers (ten in English including contributions from Russia, Holland and France, six in German, and two in French), which had not appeared elsewhere, and a summary in English of the remaining 33, are printed in this volume. Contributions of interest to the steel industry are abstracted in the Journal. Each of the main articles in the volume includes an abstract in English, French and German.

The Future of Non-Ferrous Mining in Great Britain and Ireland. A Symposium.  $8\frac{1}{2} \times 5\frac{1}{2}$  in, pp.xxvi+614. Illustrated. 1959, London:

The Institution (Price £3).

The proceedings of a symposium held in September 1958; 24 papers are presented here covering the economic geology of the principal areas, exploration techniques, the working of existing non-ferrous metal mines, mineral rights, mining taxation and metal prices. The work is ably edited and includes the text of the fourth Wernher Memorial Lecture, a report of the discussion, and a useful summary of the views expressed, subsequent written contributions, and an

excellent name and subject index.

INTERNATIONAL ATOMIC ENERGY AGENCY.

'Radiactivation Analysis'. 9\frac{3}{4} \times 6\times n, pp.141.

Illustrated. 1960, London: Butterworths.

Perce £1 10s.)

Percentage from 'Pure and this you Reprinted from 'Pure and Applied Chemistry', Vol.1, No.1, this volume is a report of the proceedings of the symposium on the subject held in Vienna in June 1959. Twelve papers are presented, including two in French. Papers in English appear with a French abstract, those in French with an English one. Questions and contributions to discussion are well reported. Papers of special interest to the steel industry are abstracted in the Journal. These include accounts of activation analysis of minor con-stituents in high alloy steels and of radiacti-vation analysis in studies on the preparation of metals of high purity and on the influence of impurities, with examples of the analysis of impurities in Al and Fe.

International Union of Pure and Applied Chemistry. 'Methods for the Determination of Toxic Substances in Air'. 9\frac{3}{4} \times 6in, loose leaf, 21 sections. Illustrated. 1959, London:

Butterworths. (Price £1 10s.)

'Proceedings. DEPARTMENT OF HEALTH. National Conference on Air Pollution, 1958'. 9×6in, pp.ix+526. 1959, Washington: US Government Printing Office. (Price \$1.75)

The first of these works presents the methods for the determination of toxic substances recommended by the Toxicology and Industrial Hygiene Division of the International Union of Pure and Applied (Chemietry, An introduction describes the Chemistry. An introduction describes the general principles of atmospheric analysis, the collection of air samples, the extraction of gases, vapour and particular matter, and the quantitative determination of toxic substances, 21 of which are dealt with in the loose-leaf pages which follow. The second work is a report of the Conference on Air Pollution held in Washington in 1958. A number of papers of particular interest to the steel industry are abstracted in the Journal.

The report is a well produced document and is very good value indeed.

'Kempe's Engineers Year Book', 1961, 2 vols.

7×5in, pp.xv+1324, pp.viii+1408. 1961, London: Morgan Brothers (Publishers) Ltd. (Price £4 7s. 6d., 2 vols in case.)

The 66th edition contains extensive revisions in nearly all its 84 sections. Among the ions in nearly all its 84 sections. Among the chapters which have been fully or partially re-written are Motor Vehicles, Forging Hammers and Drop Forging Plant, Heating, Heat and Optics, Hydraulies, and Unit of Measurement. Notable additions to other sections of the Year Book include Electrolytic Grinding and Metal Deposition, Railway Rails and Rail Fastenings, and Design of Steel Structures. Among the many useful features are short lists of recommended books. For future editions this should be extended to the chapters on Iron and Steel

and Foundry Practice.

Nacel, A. 'Herstellung von Temperguss'. 2

Aufl. 8½×5½in, pp.124. Illustrated. 1961,
Berlin: Fachverlag Schiele & Schön G.m.b.H.

(Price DM9.50.)

This short handbook on the manufacture of malleable cast iron is a German example of the now familiar inexpensive 'paperback' editions of technical books. It is printed on glossy paper which offers an ideal surface for the reproduction of good photographs, illustrating foundry practices, casting defects, photomicrographs and diagrams. This business-like publication is intended for the practising foundryman and foundry metallurgist and will serve also as a good account of modern practice for the student. Tables of compositions, properties, etc., make the book easy to comprehend even to one relatively unfamiliar with the German language. The reader is first introduced to black-heart and white-heart malleable iron and is instructed on the distinctions between these. There follows a chapter on raw materials and melting methods, in which there is an interesting section on the hot blast cupola. Foundry practice is dealt with in the clear and concise manner adopted in this book: in few words but with the accent on facts and figures. Chapters follow on casting cleaning, the malleabilizing heat-treatment process, after-treatments and mechanical

testing. This is a thoroughly good book and is highly recommended.—R. V. RILEY.
NARCUS, H. 'Metallizing of Plastics'. 7½×5in, pp.208. Illustrated. 1960, New York, London don: Reinhold Publishing Corp., Chapman & Hall Ltd. (Price £2 4s.)

This book brings together, in a handy form, much valuable information about production procedures and techniques for the metallizing of plastics and other nonconductors. The methods which are described include the copper film process, the deposition of 'electroless' nickel coating, 'gas' plating and the deposition of thick evaporated films. The book is well illustrated and concludes with descriptions of the characteristics and methods of testing of metallic deposits on plastics and of recent developments and possible applications.

NATIONAL ASSOCIATION OF CORROSION ENGIN-EERS (NACE). 'Bibliographic Survey of Corrosion'. 1956. Pub. No.60-12. 10\(\frac{2}{3}\times 8\(\frac{1}{2}\times 1\),

pp.viii+240. (Price \$27.50).

Proceedings - Short Course on Process Industry
Corrosion'. 11×8½in, pp.448. Illustrated. (Price \$25.00).

(High Purity Water Corrosion of Metals', Pub. 60-113, 11×8½in, pp.98. Illustrated, 1960, Houston: The Association. (Price \$9.00).

The NACE Bibliographic Surveys have

occupied a leading place among guides to the world's corrosion literature ever since they were first published to cover the year 1945. The present volume for 1956, the seventh in the series, maintains this high position. In contrast to earlier years, it covers only one year (subsequent volumes will do the same) and it is hoped that this change will lead to earlier publication. The 'Proceedings' consists of 22 papers presented at a short course on corrosion problems in at a short course on corrosion problems in the process industries organized by the NACE and the Department of Metallurgical Engineering of Ohio State University. 'High Purity Water Corrosion of Metals' contains a total of seven papers presented at NACE conferences in 1959 and 1960 respectively. (These papers and many of those in the 'Proceedings' are abstracted in the Journal). The three publications are rather expensive in view of their loose leaf binding but they contain a great deal of indispensable mate-rial for all those seriously interested in the

NEUGEBAUER, C. A. et al. (Editors). 'Structures and Properties of Thin Films'. 11×8½in, pp.xiv+561. Illustrated. 1959, New York, London: John Wiley and Sons Inc. (Price £6)

The 41 papers given at the New York conference on thin films in September 1959 have been published quickly, with the impromptu discussions and with author and subject indexes, in this massive book printed by a photo-offset process from typescript. The papers are arranged under six main headings according to the properties with which they deal and each group is introduced by a review of the main subject. The first two sets of papers deal with the

formation of thin solid films and with their mechanical properties. The measurement of the mechanical properties of films follows logically on the observations of structure, and there is a contribution to the difficult subject of the estimation of binding energy between a film and its substrate. Also in this section of the symposium are studies of some aspects of oxidation. Thin films are also used as convenient subjects for the study of properties common to both thin films and bulk materials. The multiplication, motion and annealing of dislocations have been observed by the transmission electron microscope technique and the results are discussed here in two papers. Other phenomena described in this section are stresscorrosion and the ordering of alloy domains on annealing a copper-gold alloy. The intro-ductory paper on electrical properties provides evidence that with proper precautions, including the use of ultra-high vacua, a 'natural' structure in thin films can be achieved and that with such films it is possible to 'determine, with relatively high accuracy, fundamental quantities of importance in the electron theory of metals'.

However, most of the papers on electrical and magnetic properties deal with effects peculiar to thin films of aggregated structure and propose models to account for the anomalies. It is shown, for instance, that bismuth films must be 'annealed' at a temperature above their melting point if they are to have a positive temperature coefficient of resistivity. The potential value of thin films as binary elements for computers has stimulated interest in superconducting films (three papers on this subject are included) and films of magnetic alloys. The review paper on magnetic properties describes aspects of the ferromagnetism of thin films. describes The modification of magnetic theory for the case of the thin film is discussed and experimental results are surveyed. The last section is on chemical interactions at surfaces. It is introduced by a long paper on molecular processes at the gas-solid interface. This deals mainly with the physical and chemical interactions of atoms and molecules, adsorption, surface diffusion and evaporation. Some of these subjects are elaborated in the succeeding papers; some striking pictures are shown of surfaces examined with the field ion microscope after removal of atomic

layers by field evaporation.

It would be impossible for any one conference to cover the whole field of thin film research but this publication is an excellent résumé of the main branches of the subject.

—K. M. GREENLAND RIDER, H. G. 'Workshop Engineering Practice'. Vol.1 Fitting; Vol.2 Lathe Work.  $8\frac{1}{2} \times 5\frac{1}{2}$ in, pp.150, 137. Illustrated. 1959, 1960, London: Tiiffe & Sons Ltd. (Price 9s. 6d. each volume.)
DEAN, F. E. 'Steel'. 7½ × 4¾in, pp.140. Illustrated. 1960, London: Frederick Muller Ltd.

(Price 9s. 6d.)

VAN VALKENBURGH, NOOGER & NEVILLE, INC. 'Basic Synchros and Servomechanisms', 2 parts. 9 × 6in, pp.118, 114. Illustrated. 1960, London: The Technical Press. (Price £1 12s.,

2 parts.)
PHILLIPS, J. 'Examples in Applied Thermodynamics'. 8½×5½in, pp.223. Illustrated. 1960, London: The English Universities

Press. (Price 17s. 6d.)

'Workshop Engineering Practice' is an introductory course by the Chief Instructor in Workshop Engineering at the Borough Polytechnic in London. It is of the most elementary character and is intended for secondary modern and junior technical schools or for those studying for the crafts examination of the City and Guilds Institute. 'Steel' is a brief but useful introduction to the steel industry. It is lively and readable and can be recommended for youngsters who are becoming interested in this 'mechanical age', as the series of which it is a part is known. The third work is part of a series of elementary technical training manuals in electricity and electronics originally duced in the United States and adapted for the use of British army recruits having no previous knowledge of the subject. Like the earlier courses, it has the minimum of text earlier courses, it has the minimum of text and is illustrated with cartoon-type drawings. The fourth book, 'Examples in Applied Thermodynamics' is a much more advanced work than any of the others and will be useful for students preparing for the subject in Ordinary National Certificate courses or beginning a university to the subject in Ordinary National Certificate courses or beginning a university to the subject in Ordinary National Certificate courses or beginning as university to the subject in Ordinary National Certificate courses or beginning as university to the subject in Ordinary National Certificate courses or beginning as university to the subject in Ordinary National Certificate courses or beginning as university to the subject in Ordinary National Certificate courses or beginning as the subject to the subject in Ordinary National Certificate courses or beginning to the subject to beginning a university engineering course such as Part I B.Sc. (Eng.) of the University of London examination in Applied Heat. It contains a wide range of examples on the subject of heat engines and each chapter is introduced by an outline of the basic theory together with a tabulated list of points to

Samarin, A. M. 'Physikalisch-chemische Grundlagen der Desoxydation von Stahl' [German translation by K. F. Lüdemann of 'Fiziko-khimicheskie osnovy raskisleniya stali', 1956].  $9 \times 6\frac{1}{2}$ in, pp.126. Illustrated. 1960, Leipzig: VEB Deutscher Verlag für Grundstoffindustrie.

The original Russian version of this book on the physico-chemical principles of the de-oxidation of steel was published in 1956 and the East German authorities obtained permission to translate in 1958. It is a pity

that, in a field where so much has been done, the difficulties of translation should cause us to wait four years to read a survey by one of Russia's most distinguished metallurgists. The work of Herty, Sims, Chipman, Schenck, Körber, Oelson, Richardson, Sloman, etc., is well known to Western scientists; great interest should therefore attach to a book that describes the Soviet contribution to

this aspect of steelmaking technology.

The book deals with the theoretical basis and practical problems in the de-oxidation of steel. Based on the latest experimental investigations, the behaviour of oxygen dissolved in liquid iron and the influence of various elements on its solubility and thermodynamic activity are discussed, The formation and precipitation of non-metallic inclusions are illustrated and particular attention is paid to the re-oxidation of steel during tapping and teeming. The connexion between de-oxidation and de-sulphurization and the reactions of nitrogen with the deoxidants are studied. As is to be expected, de-oxidation by vacuum receives a chapter to itself and tests to indicate the improvement in quality resulting from vacuum treatment are described.

The reader will find much in the experimental results to assist in the understanding of important practical matters in commercial steelmaking. On the theoretical side the author shows how the de-oxidizing power of elements may be measured by laboratory experiments and lists numerous relevant free energy equations. He insists that the nature of the de-oxidation products should be considered before assumptions are made about changes of activity coefficients though he admits that, in absence of the necessary knowledge, the rules put forward for esti-mating the effects of changing concentrations may require to be employed.

While the present book, being in German,

will be of limited value to the practical steelmaker, research workers should examine it closely and then consider whether they ought not to think more carefully about the basis on which they interpret their experimental results.—J. PEARSON.
SCANDINAVIAN COUNCIL FOR APPLIED RE-

SEARCH. 'Scandinavian Research Guide'. 2 vols.  $8\frac{1}{4} \times 5\frac{3}{2}$ in, pp.687, 486. 1960, Blinden: The Council. (Price £3 10s.)

FEDERATION INTERNATIONALE DE DOCUMEN-FEDERATION INTERNATIONALE DE DOCUMEN-TATION. 'Index Bibliographicus'. 4th ed., Vol.1 Science and Technology. 11\(\frac{3}{4}\times 8\)\frac{1}{4}\times, pp.117. 1959, The Hague: The Federation. WALES, A. P. 'Publishers' International Year Book' 1960-1961 ed. 9\(\frac{1}{2}\times 6\)\frac{1}{4}\times, pp.559. 1961: London: A. P. Wales. (Price \(\frac{1}{4}\)\frac{5}{5}\times.

These three directories are excellent examples of the invaluable material which is becoming available to information departments and libraries. The first, a directory in English of scientific and technical research organizations (exclusive of the life services) in the Scandinavian countries, is arranged in a remarkably systematic and comprehensive fashion and includes a great deal of valuable detail. The second work, a directory of abstracting and bibliographical services throughout the world, is a complete revision of the 3rd edition published in 1951. The services are arranged according to the Universal Decimal Classification and an alphabetical index is provided. The third publication, an international directory of book publishers, while it has no comprehensive alphabetical or subject index and is arranged (alphabetically) under separate countries, is no less useful and fills, like the other works, a long-felt want.

SOCIETY OF CHEMICAL INDUSTRY. 'Reports on the Progress of Applied Chemistry' Vol. XLIII: 1958. 8½×5½in, pp.911. 1960,

London: The Society.

The volume is divided into eight sections, Fuel and Fuel Products, Organic and In-organic Chemistry, Metals, Biological Pro-ducts, Textiles and similar materials, Chemical Engineering and Hazards, and Agriculture and Food. The section on Metals is abstracted in the JISI; it provides a valuable review (with excellent lists of references) of work during the year in physical metallurgy, extraction and refining of

metallurgy, extraction and refining of metals, corrosion, and electrodeposition.

STANIAR, W. (Ed.) 'Plant Engineering Handbook', 2nd ed. 9×6in, pp.xv+42 sections (not continuously paginated). Illustrated. 1959, New York, London: McGraw-Hill Book Co. (Price £9 2s.)

The second edition of this bandbook is

The second edition of this handbook includes a complete revision of the sections contained in the first edition, published in 1950, and some 34 additional subjects are also included. The handbook is a useful general reference for those in industry, responsible for organization, design, construc-tion, operation, and maintenance. It should be noted, however, that the quantitative information and statistics are given in American units, e.g. short tons are used throughout, and thus great care should be taken when using this book: also the standards referred to are those of the American Standards Association.

The book is intended to assist in solving

some of the day-to-day problems in industrial plants and presents in compact form much of the detailed material specialized engineering handbooks and reference books. Subjects covered range from basic industrial costs and their reduction, management engineering including incentive wage methods and job evaluation to engineering practices, types of construc-tion, heating, fire protection, water and power supplies, general mechanical and chemical engineering, electrical engineering to a limited extent, instrumentation and automatic control systems, and the problems of automation. Sections are also included on automatic weighing and proportioning, mechanical handling, elementary graphical mathematics, glass, plastics and rubber, and basic information on patents and copyrights.

Many of the sections conclude with bibliographies, but these are mainly confined to American publications which may be difficult to obtain in this country. The standard of presentation is good and concise, though the system of page numbering by sections may be somewhat confusing, particularly as the contents of each section are not given page reference numbers within the section.

SZABÓ, I. 'Hütte: Mathematische Formeln und Tafeln'. 1 Auflage, pp.xv+287. Illustrated, 1959, Berlin: Verlag von Wilhelm Ernst & Sohn. (Price DM. 19.80) This book brings together.

This book brings together in a convenient format a large and far-reaching collection of formulas and tables, with concise explanatory matter in some cases. The main headings are: tables; arithmetic (mcluding complex numbers); circular and hyberbolic functions; differential and integral calculation; linear vector algebra and vector analysis; analytical geometry; functions of a complex variable; differential equations; probability calculation and mathematical statistics; practical mathematics and formulas covering areas of plane figures and volumes of solids. There is a bibliography of 106 classified references.

THE UNITED STEEL COMPANIES LTD. 'Roll Pass Design'. 9×6in, pp.280. Illustrated.

1960, Sheffield: The Company. (Price £3).

This book, published by The United Steel
Companies, has been very ably compiled.
The authors are responsible for most of the
roll pass designs which are discussed, and are all well versed in the various aspects of this complex subject. Up to the present time there has been very little written and published in Britain on the very important subject of roll pass design as it is practised in rolling mills in this country today. It is only in recent years that publications on roll pass design have been made available, and these mostly by American and conti-nental writers. A publication by a British operator is a most welcome addition to a very limited library in this field.

The opening chapters of the book give

the reader an insight into the history of the steel industry and a close look at the various characteristics of hot rolling which are important both to the roll designer and

mill operator. Knowing the correct application of the various qualities and hardnes of rolls is most important and this subject is outlined clearly giving also the wear properties of the roll materials. The majority of the book is devoted to design, beginning with the more simple uniform sections and leading the reader on to the unsymmetrical and complex sections that are every-day rolling mill problems, such as rails, fish-plates and sleepers. Each design that is presented is well illustrated and thoroughly analysed, so that the mill operator who is not usually well acquainted with the problems affecting roll pass design can readily come to grips with what has always been a somewhat 'mystical' and 'far away' subject. As a reference book 'Roll Pass Design' should be of great assistance to all roll designers and a valuable source of information for all those connected with the

operation of rolling mills.—D. T. JONES. VICKERY, B. C. 'On Retrieval System Theory 8½ × 5½in, pp.x+159. Illustrated. 196 London: Butterworths. (Price £1 10s.) 1961.

Information usually reaches the inquirer indirectly, so that he has to rely on indexes and classifications; but few people understand very much about the workings of these systems. Mr Vickery has now provided an account of the theoretical basis of the hitherto rather empirical science of informa-tion retrieval. He describes in logical and mathematical terms the processes of abstracting and classifying information, by machine or by conventional methods, and of locating it again when it is wanted. The aims are retrieval efficiency (to select all the relevant documents and none of the irrelevant) and economic efficiency (which cuts this down to what is practicable with reasonable expenditure of labour, materials, time and money).

The author describes some mechanical systems, but emphasises that machines alone are not the answer: they are not only expensive but tend to be inflexible, and are only as efficient as the classification system they use. It is here that research is urgently needed, both into theory and practice; Mr Vickery's analysis will have served a useful purpose if it encourages more research workers to study this problem on which, as the bulk of scientific literature becomes more unwieldy, their own supplies of infor-

mation will increasingly depend.

M. WRIGHT WIRTSCHAFTSVEREINIGUNG EISEN-UND STAHL-INDUSTRIE. 'Statistisches Jahrbuch', 1959-60.
8½×5¾in, pp.x+297. 1961, Dusseldorf:
Verlag Stahleisen. (Price DM. 12).
This invaluable and well known annual

publication provides statistics of iron and steel production and trade for Germany and the world. The information is clearly presented and sensibly arranged.

## **NEW PUBLICATIONS**

These titles are also available on index cards in advance of publication in the Journal, each title being classified under the Universal Decimal system (UDC). Details and subscription rates can be obtained from the Secretary, The Iron and Steel Institute.

Ahrens, L. H., Taylor, S. R. 'Spectrochemical Analysis'. 2nd ed. Addison-Wesley series in Analysis . 2nd ed. Addison-Wesley series in the Earth Sciences. 9.2 6in, pp.xxiii+454. Illustrated. London, Reading (Mass.), 1961: Pergamon Press; Addison-Wesley Publishing Co. Inc. (Price £5 5s.)

American Society for Testing Materials.

'Punched Cards for High Temperature Strength Data on Metals and Alloys'. Group II. Iron and steel including the AISI stainless steels. Group III Superalloys, refractory alloys and miscellaneous alloys. [25 cards  $10\frac{1}{2} \times 8$ in, pp. Code book 9×6in, pp.11] Philadelphia, 1961: The Society. (Price \$7.50 per group including code book; memters \$6.00).

AMERICAN SOCIETY FOR TESTING MATERIALS
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- AMERICAN SOCIETY FOR TESTING MATERIALS. 'Symposium on Acoustical Fatigue'. STP. No.284. 9×6in, pp.v+65. Illustrated. Philadelphia. 1961: The Society. (Price \$2.50; Members \$2.00.)
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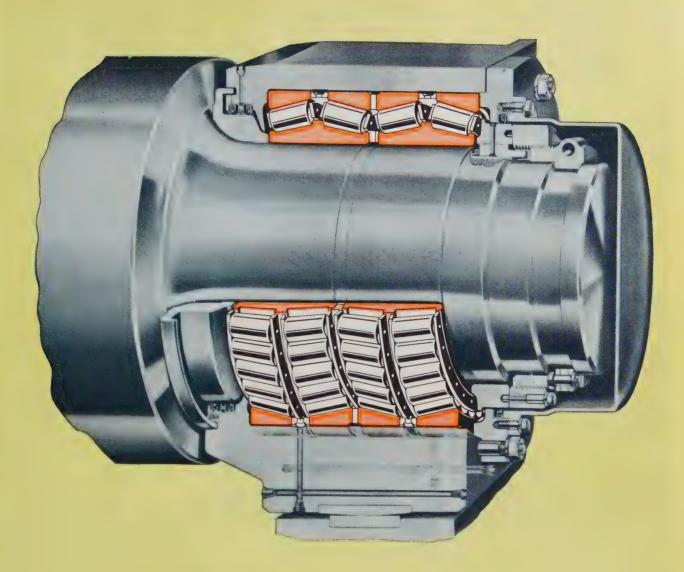
9.20.)
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# UNSURPASSED IN THE MOST ARDUOUS ROLLING MILL DUTIES

British Timken, Duston, Northampton, Division of The Timken Roller Bearing Company. Timken bearings manufactured in England, Australia, Brazil, Canada, France and U.S.A.





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Pouring Hot Metal in a 200 Ton Open Hearth Furnace, Abbey Works, The Steel Co. of Wales, by courtesy of whom this photograph is reproduced

# REAVELL-ASKANIA REGULATORS

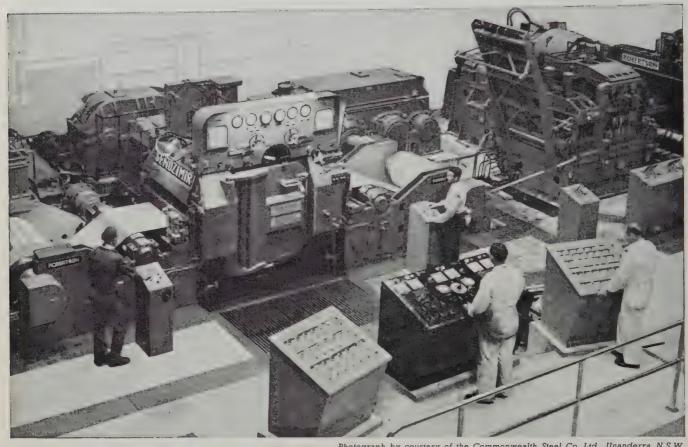
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Photograph by courtesy of the Commonwealth Steel Co. Ltd., Unanderra, N.S.W.

Sendzimir ZR 22 – 42 in. Reversing Cold Mill for rolling carbon and stainless steel strip.

Installed by Robertsons at the works of the Commonwealth Steel Co. Ltd., New South Wales.



W. H. A. ROBERTSON & CO. LTD. BEDFORD • ENGLAND

LICENSEES FOR THE BUILDING OF SENDZIMIR COLD REDUCTION MILLS AND PLANETARY HOT MILLS AND HALLDEN FLYING SHEARS

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# STELVETTE

# plastic bonded to steel has put a new face on the

# SADIA TWO-PLUS

# Water Heater



The use of Stelvetite in the manufacture of the Sadia Two-Plus provides a perfect example of the economy it achieves. Aidas Electric Ltd. decided to open a satellite factory at Salisbury to make this popular heater. The factory was planned around the exclusive use of Stelvetite for casings, thus eliminating the need for a paint shop because Stelvetite has a finished surface.

As a result capital costs were cut by  $17\frac{1}{2}\%$  and production started three months earlier than would otherwise have been possible. This economy is additional to the cost and time saved in actual manufacture

The P.V.C. surface of Stelvetite is impervious to superficial knocks, chips and scratches, yet it is decorative, heat resistant, an insulation and its colour holds fast.



Plastic, bonded to Steel

Accepted by the Design for

"Design Index"

to Aidas Electric, Sadia Works, Rowdell Road, Northolt, Middlesex.

All enquiries about the Sadia Two-Plus Water Heater should be addressed

# \*STELVETITE-made in co-operation with BX Plastics Ltd. by

Write to us at Dept. JS . Shotton . Chester . for full information

# STEPHENS'

# Super Grade Low Alumina Silica Brick

FINE SILICA CEMENT FOR SETTING SILICA BRICK

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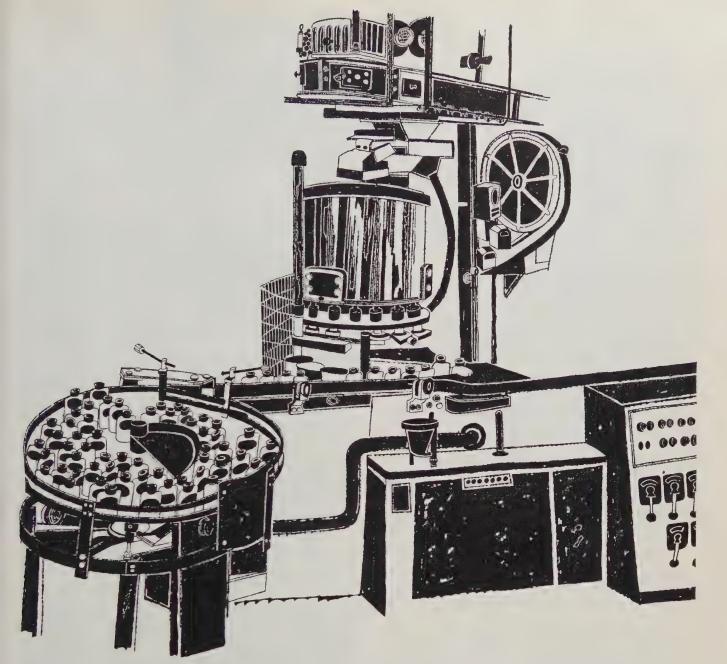
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THE MONEY THAT MANAGEMENTS SAVE THROUGH MOBIL ECONOMY SERVICE

More than £3,000 saved in a year at Reckitt & Sons Ltd

RECKITT AND SONS LTD of Hull, asked Mobil to suggest improvements in the maintenance and lubrication systems at four of their factories. Mobil advised using a card index system to ensure regular and correct lubrication, reducing the number of oils stocked, reclamation of used oil, and several other schemes of preventive maintenance and purchasing rationalisation.

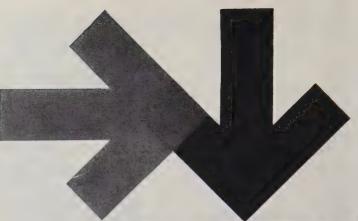
In one year, after applying Mobil's recommendations, Reckitt made a direct saving of over £3,000. A further immediate saving of over £900 is probable.

World-wide experience of industrial lubrication has been built up by the Mobil Organisation over 90 years. The Reckitt case is one of hundreds in which the recommendations of the Mobil Economy Service have successfully cut lubrication and maintenance costs. Specialist knowledge methodically applied is the value of the Mobil Economy Service. The total lubrication requirements of a business and the minimum number of lubricants in the smallest quantities it needs must be assessed. And everyone concerned must know how to achieve the best lubrication results with the greatest

economy of labour. These are tasks undertaken by the Mobil Economy Service—and the big savings resulting from its recommendations are a measure of its success.



# THIS MOTOR SAVED £2,000



# here's how...

27 breakdowns in seven years. The cause? Insulation failure. The electric motor on a four-ton stripper crane at Workington Iron and Steel Company kept breaking down, so in 1953 the 50 hp Class A motor was replaced by a Class B insulated motor of the same rating specially designed for heavy duty—but there were still 5 insulation breakdowns over the next three years.

Because of production losses and the cost of rewinds the motor was finally rewound in 1956 with Class H insulating materials—silicones combined with glasscloth and mica.

Result? In the words of Workington Iron and Steel Company, 'No breakdowns since that date'. A saving of £2,000 in rewind costs with no further losses in production due to insulation failure.

Contact your Midland Silicones area office and ask for a list of manufacturers and rewinders experienced in silicone insulation and for copies of our regular news bulletin "MS News for Industry."



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(Associated with Albright & Wilson Ltd and Dow Corning Corporation)

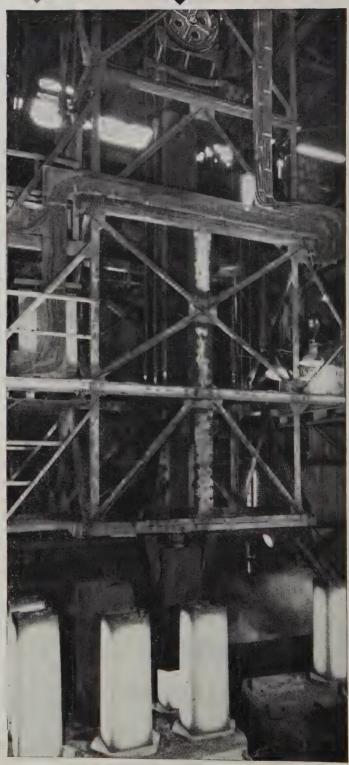
## first in British Silicones

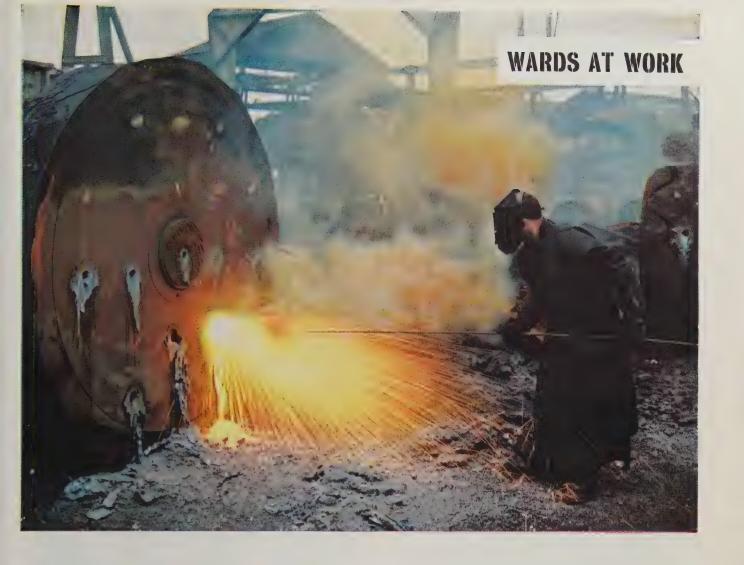
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# He turns base metal into gold!

No alchemist this, but a skilled scrapman in a Ward scrapyard. With his highly specialised experience, he can quickly prepare large masses of scrap for reduction to furnace sizes. Not only steel and iron, but all non-ferrous metals are handled too, both under strict metallurgical control. At scrapyards all over the country, equipped with the most modern plant, Wards handle thousands of tons of metal a day, and they are proud to be the leaders in this important industry.

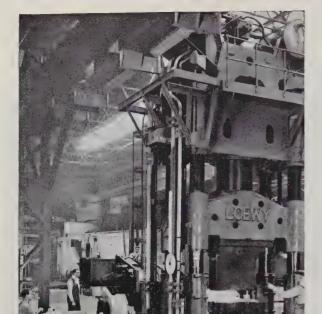
Helping to feed the furnaces with carefully graded scrap is only one activity of the Ward Group of Companies whose products and services cover almost every branch of industry.

Serving Industry Around The World THOS. W. WARD LTD



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61



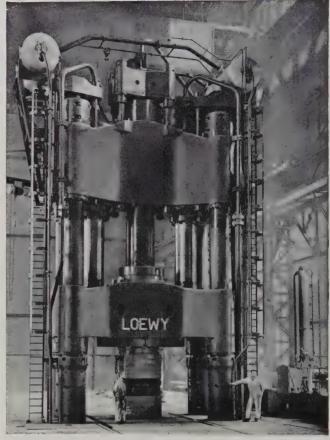
800 tons forging press



1750 tons forging press Both the above presses were supplied to Thos. Firth & John **Brown Limited.** 



# FORGING PRESSES



6000 tons forging press

Supplied to The Rotterdam Dockyard Company Limited

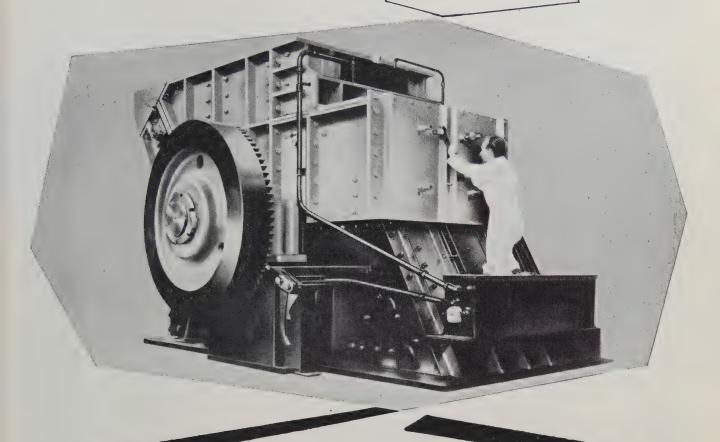
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THE LOEWY ENGINEERING COMPANY LTD.

BOURNEMOUTH ENGLAND

# Crushers



# HARD-WEARING Did you know that the largest hammermill ever produced in Britain was built by EXPERTLY-DESIGNED **CRUSHING** PLANT

G.E.C.? Or that G.E.C. can supply any type of crushing plant for any application? Besides the extremely wide range of crushers available, G.E.C. design plant for special applications, as well as complete ore-treatment installations. The soundness of design, excellence of workmanship, and hard-wearing qualities of these crushing plants are well-known.

Efficient blenders, expertly-designed crushers, the world's largest range of screens and feeders -all are products of the skill, craftsmanship and experience of one of the world's largest engineering organisations.

rely on the experience of



# new process

# DIRECT REDUCTION OF IRON

Under a non exclusive arrangement with the R-N Corporation of New York, Head Wrightson will engineer and supply throughout the world complete plants using the R-N process for the direct reduction of iron ore with subsequent gangue

separation and the production of briquettes of a very high iron content.

We invite you to write for full information on this new process. Our engineers are available to discuss the suitability of your own ore to this new method of direct reduction.

# REMEMBER

- The R-N process is not dependent upon the availability of coking coal.
- Capital and running costs are competitive with other direct reduction processes, but the R-N
  process has the technical advantage of subsequently removing the gangue.
- The R-N process can use ores and coal that today are not suitable for blast furnace plant.
- The R-N product is an excellent feed material for electric arc and open hearth furnaces as well as a convenient cooling material in oxygen converters.

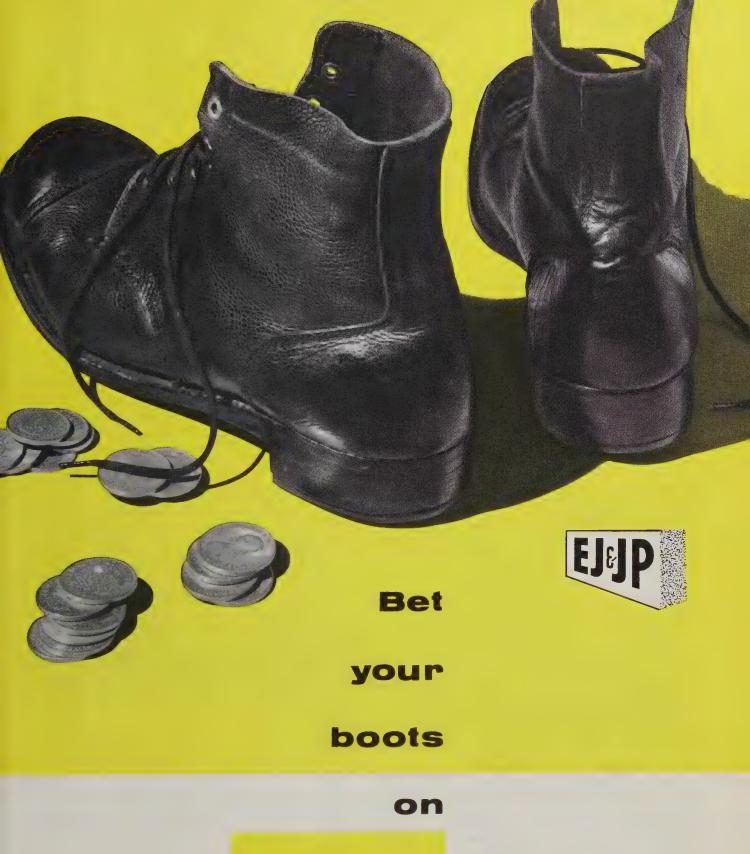


# HEAD WRIGHTSON

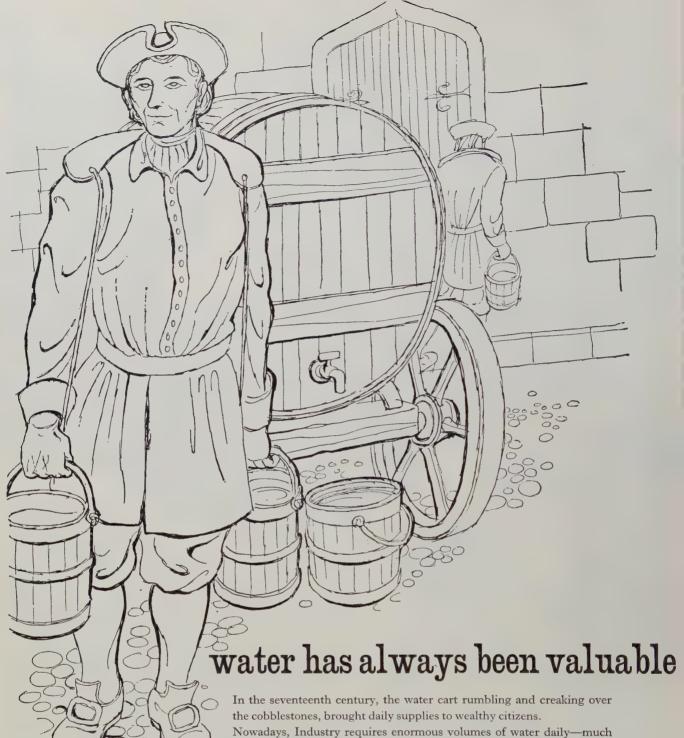
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PEARSON refractories!



Nowadays, Industry requires enormous volumes of water daily—much of it recovered from trade wastes. Eimco, manufacturers of clarifiers, thickeners, flotators and filtration plant plays an important part in this recovery.

Eimco's facilities include testing, process design, manufacture and installation. Why not discuss your effluent problem with us?

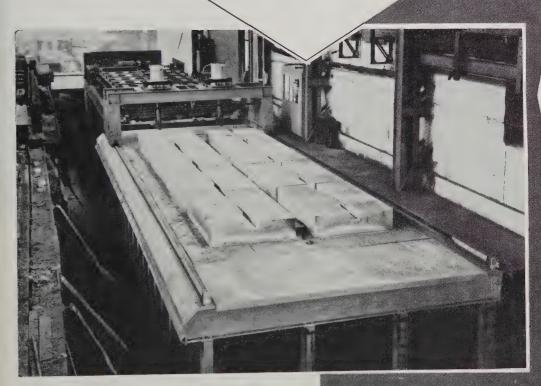


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# One of the many installations using KIP

LIGHTWEIGHT INSULATING REFRACTORIES



Photograph reproduced by courtesy of Appleby — Frodingham Steel Company (Branch of The United Steel Companies, Ltd.) and Stein and Atkinson, Ltd.

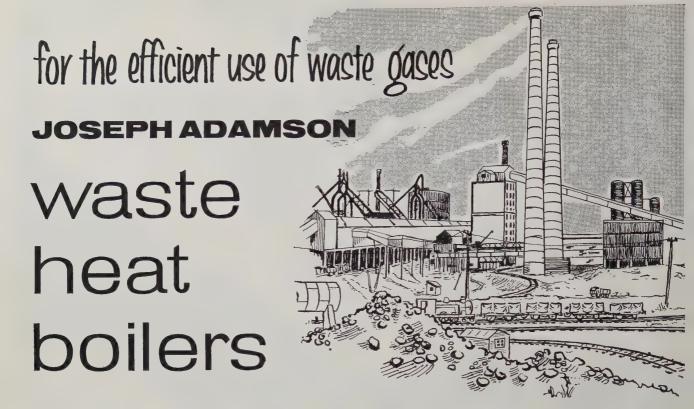


Electric soaking pit, designed and built by Stein and Atkinson Ltd., for the Appleby—Frodingham Steel Company (Branch of the United Steel Companies Ltd.), Scunthorpe

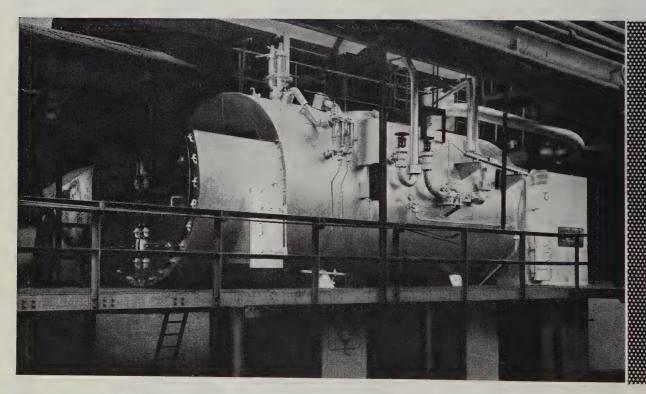


STORRS BRIDGE WORKS, LOXLEY, SHEFFIELD Phone: 43844/5

KIP/30.



The Joseph Adamson Waste Heat Boiler is designed to make efficient use of the waste gases leaving open-hearth furnaces, reheating furnaces, soaking pits, gas retorts, etc. The straight-through fire tubes have a high ratio of length to bore, giving about 90% tube efficiency and providing a large area of heating surface in a comparatively small space. Brickwork setting is not required and air infiltration is thus avoided. A feature of Joseph Adamson Waste Heat Boilers is that a special cleaning device can be provided in the outlet chamber to allow the tubes to be cleaned while the boiler is at work.





JOSEPH ADAMSON & CO. LTD. P.O. BOX 4 · HYDE · CHESHIRE

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THE ADAMSON GROUP



PLATINUM – an indispensable metal

World consumption of the platinum metals has been increasing far more rapidly than the overall rate of industrial growth. New applications have called for a larger output than ever before, and platinum has become a vital element in technical progress.

To meet this demand Johnson Matthey operate the largest platinum refinery in the world, handling the entire output of the world's largest producer of the platinum metals – Rustenburg

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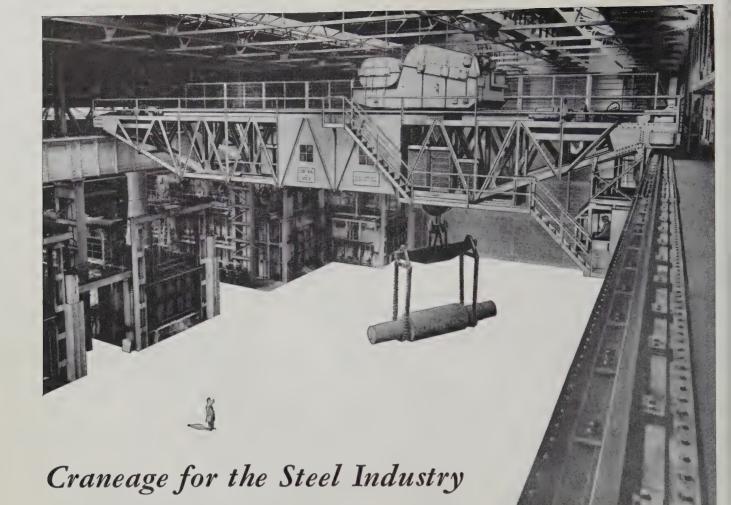
Johnson Matthey

Our quarterly journal "Platinum Metals Review", devoted to applications of the platinum metals in industry and research, is free on request.

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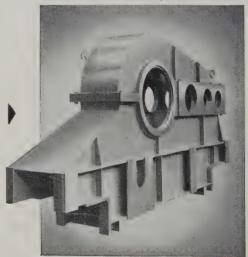
75-79 Eyre Street, Sheffield, 1. Telephone: 29212



A 130/40 tons heavy duty electric overhead travelling crane handling forgings in the Bessemer Heat Treatment Department at Messrs. Thos. Firth & John Brown Ltd., Sheffield.

Fabricated steel gearboxes are a salient feature of Clyde-Booth practice. In this example the gearbox and crab side members form a monobloc box-section of great strength and rigidity.

Upper photograph by courtesy of Messrs. Thomas Firth & John Brown Ltd.

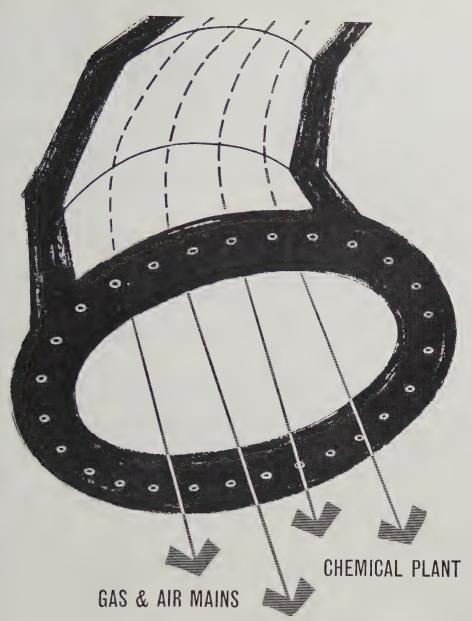




CLYDE CRANE AND BOOTH LIMITED

Incorporating

Joseph Booth & Bros., Union Crane Works, RODLEY, Leeds. Tel: Pudsey 3168. Grams: 'Cranes Rodley Telex'. Telex 55159 Clyde Crane & Engineering Co., Mossend, BELLSHILL, Lanarkshire. Tel: Holytown 412. Grams: 'Clyde Motherwell Telex'. Telex 77443



# EXHAUST SYSTEMS HEATING VENTILATION

Lobster back pipework specials and other steel fabrications are made wonderfully well to any specification.

# **CROMPTON & HARRISON LTD.**

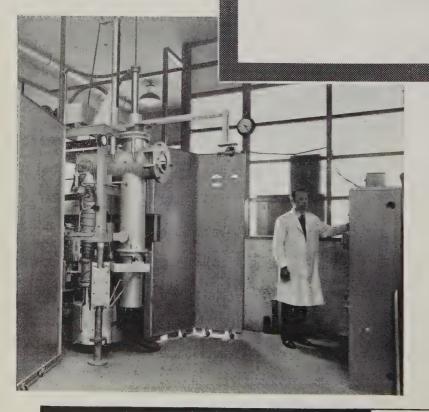
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# VACUUM-ARC MELTING

FOR PRODUCING
HIGH DENSITY INGOTS
FREE FROM REFRACTORY
CONTAMINATION WITH
THE ADVANTAGES OF
VACUUM MELTING



# "SPEEDIVAC"

# CONSUMABLE ELECTRODE VACUUM ARC FURNACE

This furnace, equipped with an automatic electrode feed, is designed to accommodate a 36-inch long consumable electrode for the production of ingots of sizes up to a maximum diameter of 6 inches and varying lengths up to 15 inches.

The furnace is designed for the melting of refractory high-temperature metals such as molybdenum titanium, zirconium, as well as the remelting o steel alloys, etc.

A powerful "SPEEDIVAC" pumping system com prising mechanical rotary and vapour booster pump is operated remotely from a control cabinet.

LABORATORY VACUUM AND ARGON ARG

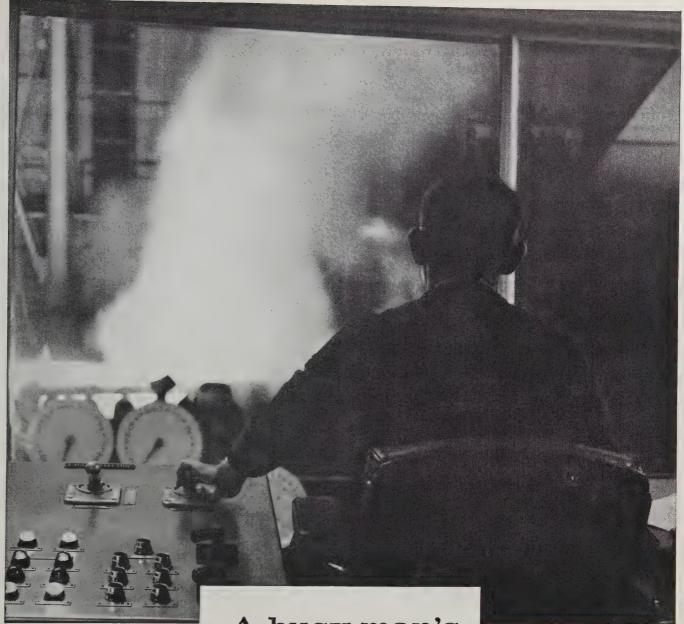
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ENGLAND



# A busy man's guide to Britain's steel progress

WINSTON CHURCHILL kept his finger on the pulse of things by asking for important information "on one side of a sheet of paper".

The post-war achievements of the British steel industry would fill a book. Here, for the busy man whose eye we have this minute, is an account of what is happening now.

**PRODUCTION** The British steel industry produced over 24 million tons of steel in 1960 – compared with 20 million tons in 1959. Output is now about *double* the pre-war figure. Production of alloy steels—especially stainless steel—is expanding particularly rapidly.

**PLANT** Since the end of 1946, over £900,000,000 has been spent on development. Continued modernisation and expansion – now costing some £200,000,000 a year – will provide steel capacity for over 34 million tons by 1965. Pig iron output per furnace and open hearth steel output

per furnace are both more than double pre-war. With the need for ever-increasing efficiency and economy, ore beneficiation has made great strides and fuel consumption per ton of iron has been reduced by about 25% since the war. Use of oxygen for steelmaking is rapidly increasing.

**INDUSTRIAL RELATIONS** The industry keeps its remarkably good record for settling industrial disputes without recourse to strike action. British steel workers are often sons and grandsons of steel workers, richly endowed with traditional skills. Making steel exactly to specification is more than a commercial requirement; it's a matter of pride.

**PRICES** British steel prices have been keenly competitive since the war with those of other major European producers and well below the American price level – and the quality of British steel is unsurpassed.



"...they're
COWANS SHELDON
100 tonners"



South Durham Steel & Iron Co. Ltd. RELY ON COWANS SHELDON

Designed and built by COWANS SHELDON to B.I.S.R.A. Specification & B.S.S.466, two 100 TON×110 FEET SPAN STEELWORKS OVERHEAD CRANES with 30 ton auxiliary hoists installed this year in the mill bay of the Cargofleet works.



# COWANS SHELDON

CARLISLE · ENGLAND

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# "STELLITE" RESISTS WEAR AT HIGH TEMPERATURES

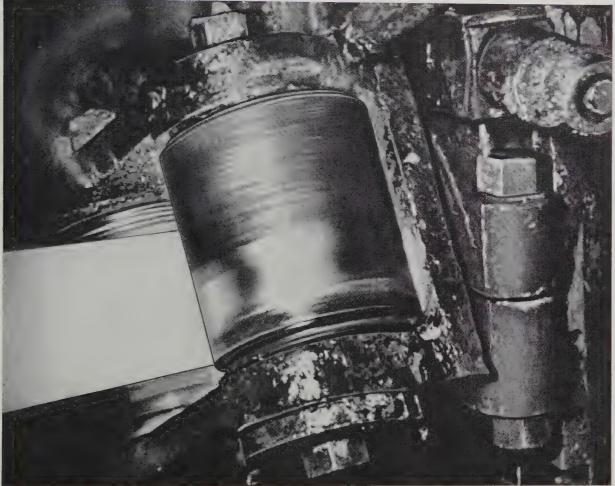


Illustration shows "Stellite" faced rolling mill guide in action

Throughout all branches of the Steel Industry Deloro Stellite alloys have proved to be extremely resistant to arduous conditions of abrasion and heat. Components protected with these alloys show a life increase of up to 500%. Applications include hot shear blades, ingot tong bits, twist rolls, etc.

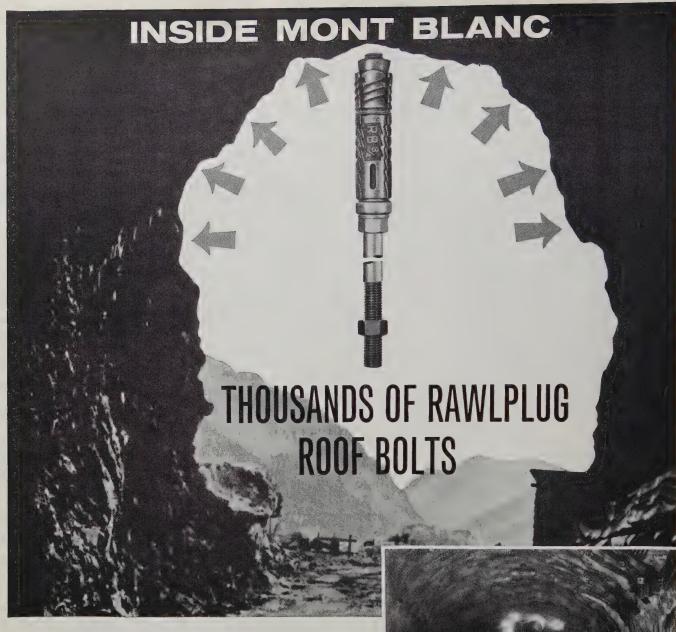
"Stellite" is applied by normal welding processes, or the recently developed Spray-Fuse and Powder Welding methods.



Our area engineer will be pleased to call and give any advice you may require

DELORO STELLITE LIMITED · HIGHLANDS ROAD · SHIRLEY · SOLIHULL · WARWICKSHIRE DELORO STELLITE DIV. OF DELORO SMELTING & REFINING CO. LTD. BELLEVILLE · ONTARIO · CANADA

The names "Deloro" and "Stellite" are registered trade marks



In this gigantic enterprise—a 7 mile road tunnel through the rock heart of Mont Blanc—the accent everywhere is on ultra-modern efficiency, both as to machinery and methods. These include the use of thousands of Rawlplug Roof Bolts—for bolting rock strata over the tunnel, for holding steel roof-supports and fixing protective netting, and for holding rigidly in place the enormous ventilation and extraction tubes. Rawlplug Roof Bolts are one of the many Rawlplug Fixing Devices for speed and strength.

#### RAWLPLUG ROOF BOLTS have these special features:

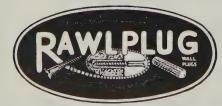
- (1) Shields and studs can be placed and hand tightened at desired depth prior to assembly of plates, beams, etc.
- (2) No setting tools or special gear required.
- (3) Can be tightened either with an impact wrench, nut runner or manually, using keys or torque spanners.
- (4) Rawlplug Roof Bolts are recoverable.

Write now for full technical details for your reference files.



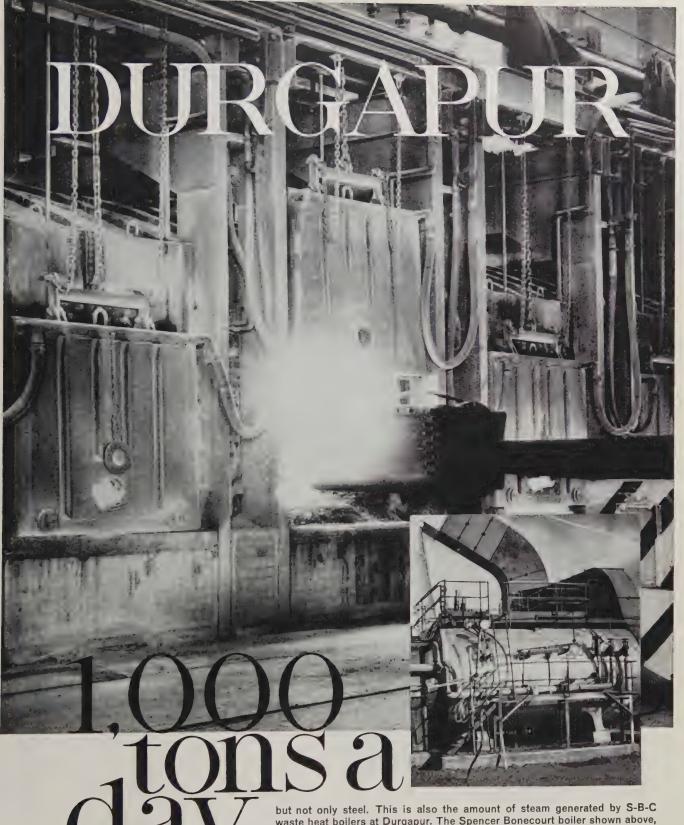
Photographs by courtesy of Societa Italiana per Condotte D'Acqua di Roma

Fixing steel wire netting with Rawlplug Roof Bolts to protect personnel from falls of rock. Here the tunnel has reached a depth of 2,300 metres of the total 5,850 metres of the Italian Section. (Atlas-Copco "Lion" rock drills are driving the tunnel from a 30-ton, four-decked drilling platform).



## FIXING DEVICES FOR SPEED AND STRENGTH

THE RAWLPLUG CO. LTD · CROMWELL ROAD · LONDON · SW7



but not only steel. This is also the amount of steam generated by S-B-C waste heat boilers at Durgapur. The Spencer Bonecourt boiler shown above, inset, and six others like it, produces from 10,000 to 20,000 lbs of steam per hour – at 200 lbs per sq. in. S-B-C waste heat boilers were chosen by The Wellman Smith Owen Engineering Corporation Ltd., to operate in conjunction with their 200 ton open hearth melting furnaces for Indian Steelworks Construction Co. Ltd. On any question relating to the recovery of waste heat, S-B-C are the people to contact. Write in today for the illustrated booklet: "Waste Heat Recovery".

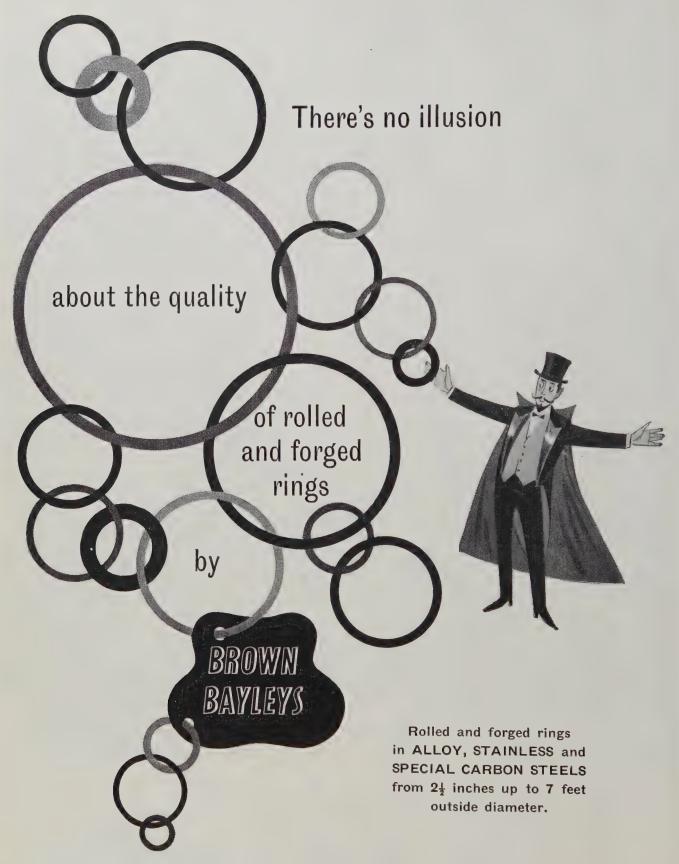
SBC

SPENCER-BONECOURT-CLARKSON LTD. Leaders in Waste Heat Recovery A subsidiary company of Babcock & Wilcox Ltd.

28 EASTON STREET . LONDON . W.C.1

Telephone: Terminus 7466

IPSBC21



BROWN BAYLEY STEELS LIMITED . SHEFFIELD

# Factory Heating-2

It is impossible in this Data Sheet to describe in detail every type of electric heater on the market, but a representative selection is dealt with below. Each type of building presents its own problem, and the best plan is to seek advice from your Electricity Board, who will be pleased to help.

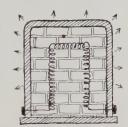
#### 'OFF PEAK' ELECTRIC HEATING

Because the 'off peak' load makes use of generating and distributing equipment when it would otherwise be idle or underloaded, it is attractive to the Electricity Boards, who offer cheap 'off peak' tariffs. Three types of 'off peak' heating systems are available, namely:

(a) Hot water storage heating: This consists of a conventional hot water radiator or panel heating system through which hot water from a large storage vessel is circulated. The water in the storage vessel is heated electrically during the 'off peak', low tariff hours and is circulated when required through the radiators or panels.

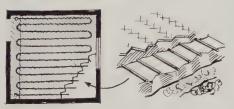
(b) Block storage heaters: These heaters consist essentially of a number of firebrick blocks which are heated up during the 'off peak' hours by means of

suitable electric heating elements. The storage heaters are clad with a layer of suitable heat-insulating material and are housed in a sheet metal casing, the design being such that the stored heat is gradually dissipated throughout the day by means of radiation and



convection from the casing. The great advantage of this method is that these heaters can easily be installed in existing buildings.

(c) Floor warming: In an 'off peak' floor warming installation, electric heating cables or ducts housing



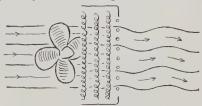
Plan view of room

Isometric view of heating cable

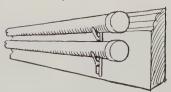
withdrawable cables are embedded in the concrete floor of the building. The cables are switched on and the floor is heated up during the 'off peak' hours, and the mass of concrete and screed of the finished floor has sufficient thermal storage capacity to heat the building during the period when current is not available. This method is only applicable to new buildings or buildings where new floors are being constructed.

#### DIRECT ELECTRIC HEATING

(a) Unit heaters: These consist of a bank of electric heating elements fixed in a casing on which is mounted a fan which draws or blows air over the heating elements and discharges it, usually through adjustable louvres, in the required direction. A number of such units are mounted on the walls or stanchions or hung from the roof members in appropriate positions throughout the works.



(b) Infra-red heaters: These consist of heating elements usually of the sheathed metal or silica tube type mounted in a polished reflector. They operate at temperatures from 700 to 900°C, and give off the greater part of their heat output by radiation. They are mounted overhead in a similar way to unit heaters and are particularly useful for providing local areas of comfort in spaces not otherwise heated.

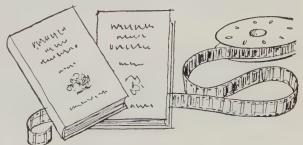


(c) Tubular heaters: These, as the name suggests, take the form of tubes approximately 2" in diameter containing an electric heating element and are available in lengths from 2 to 17 ft. The normal loading is 60 watts per foot run and the surface temperature is from 180 to 200°F. They are usually placed round the walls at skirting level, but also can be used at high level in order to prevent downdraughts from windows and skylights.

For further information get in touch with your Electricity Board or write direct to the Electrical Development Association, 2 Savoy Hill, London, W.C.2. Telephone: TEMple Bar 9434.

Excellent reference books on the industrial and commercial uses of electricity and reprints of articles and papers are available.

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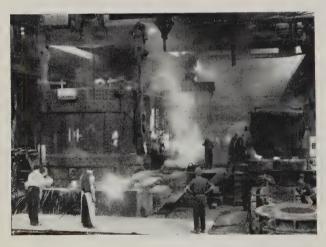


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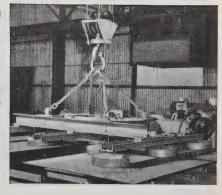
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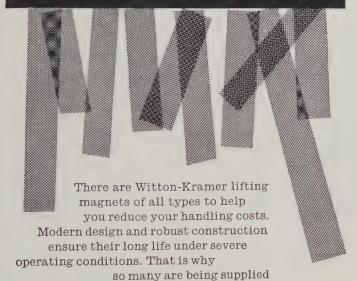


Lifting pig iron at Round Oak Steelworks Ltd.



Lifting four ingots at the works of Taylor Brothers & Co. Ltd., Trafford Park. The total lift is about 13,440 lbs.



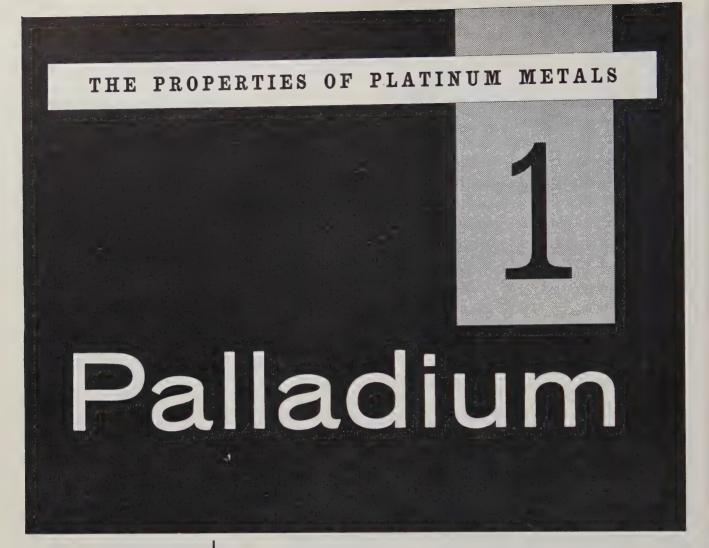


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#### TABLE OF PROPERTIES

Crystal Structure Lattice Constant a at 20°C Density at 20°C Melting point **Boiling** point **Neutron Capture Cross Section** for Thermal Neutrons Electrical Resistivity at 0°C Temperature coefficient of electrical resistance, 0-100°C Youngs Modulus

8 barns 10.0 microhm cm 0.0038  $16 \times 10^6$  p.s.i. 12 t.s.i. Tensile Strength (annealed) Hardness-annealed 37 D.P.N. Electro-deposited 190-400 D.P.N.

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1552°C

3200°C

 $12.02 \, g/cm^3$ 

Further technical information can be obtained from the Company's Development and Research Department or from Engelhard Industries Limited, Baker Platinum Division, 52 High Holborn, London WC1, who market and fabricate platinum group metals produced by The International Nickel Company (Mond) Limited.

Palladium has the lowest density and the lowest melting point of the nlatinum metals

In the annealed state it is a soft ductile metal, the mechanical strength and hardness of which may be greatly increased by cold working. Thus, after 50% reduction in cross-sectional area, the hardness increases from about 40 to about 110 D.P.N. and the tensile strength increases from about 12 to 21 t.s.i.

The mechanical strength may also be increased by alloying with other platinum metals. For example, by alloying with 4.5% ruthenium the tensile strength in the annealed condition is increased to 23 t.s.i. In the electro-deposited form a hardness in the order of 300 D.P.N. can be obtained.

Its reactions with hydrogen are of particular interest. At room temperature palladium absorbs nearly 1000 times its own volume of hydrogen. At temperatures between 100 and 200°C and pressures approximating to atmospheric, solubility of hydrogen falls off rapidly and gas absorbed at lower temperatures is released. Hydrogen diffuses readily through heated palladium and this provides the basis for some methods of purifying this gas. Finely divided palladium is an exceptionally active catalyst for hydrogenation and dehydrcgenation reactions and is particularly suitable for the promotion of these reactions at low temperatures and pressures.

The general corrosion resistance of palladium is only slightly inferior to that of platinum. It is attacked by some oxidising acids and by hot concentrated sulphuric acid and forms a superficial oxide film when heated in air at temperatures between 400 and 800°C.

Palladium may be readily fabricated, in the form of wire, sheet, foil, leaf and ribbon, by cold working. Finished articles may also be produced by rolling, spinning and drawing.

Palladium can be joined by fusion welding, brazing or soldering and may be pressure welded at temperatures below its melting point.



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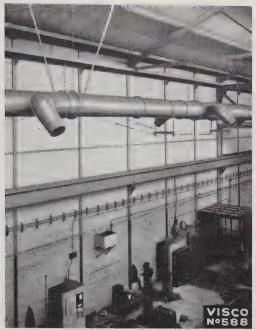
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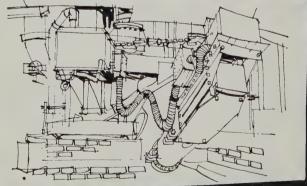
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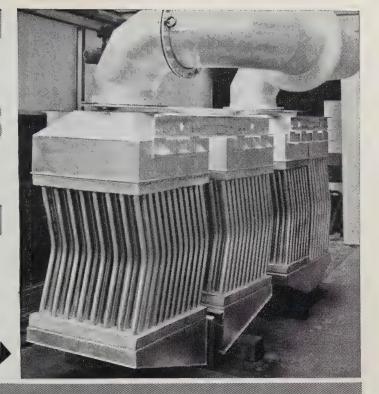


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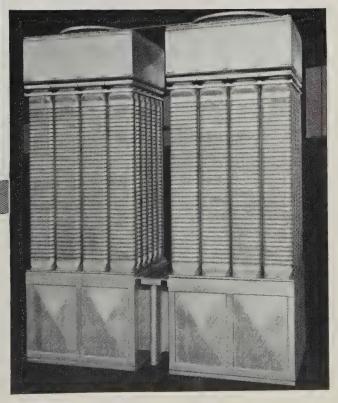
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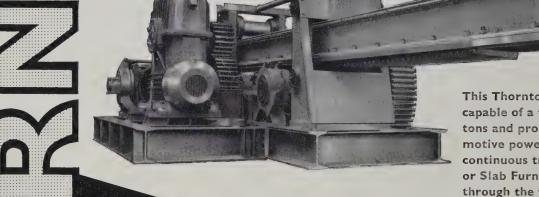
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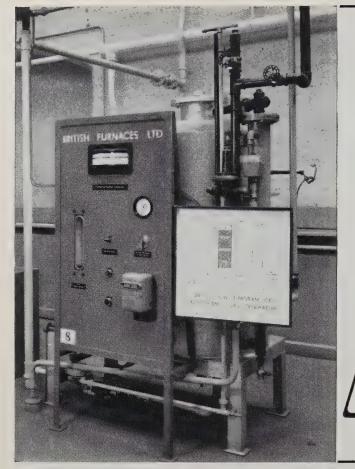
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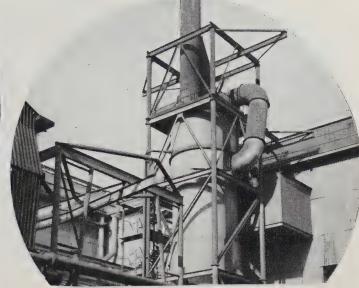


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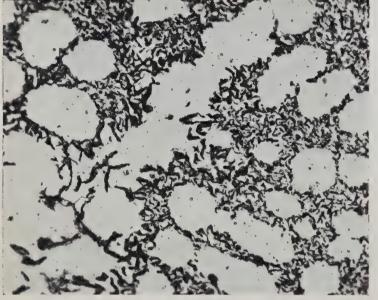
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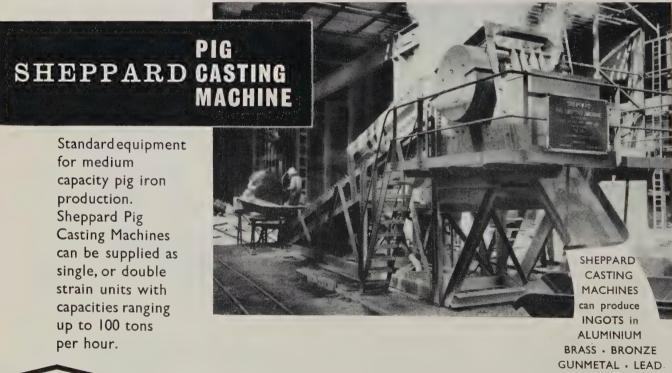
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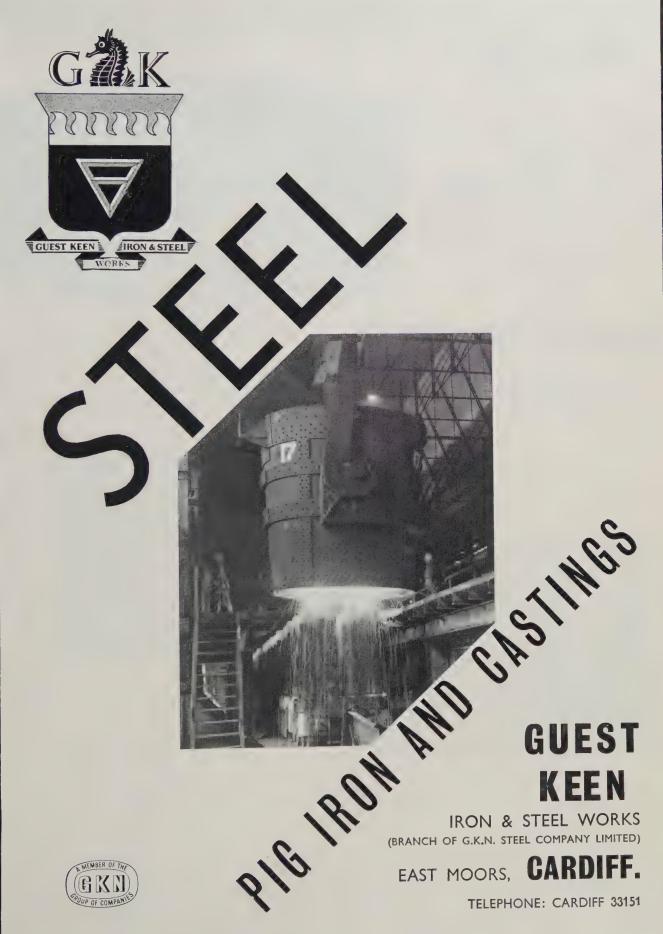
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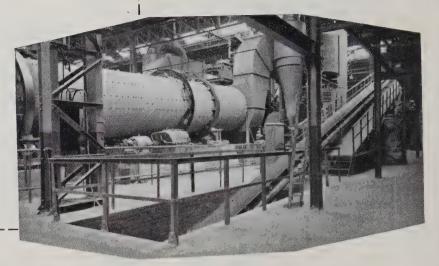
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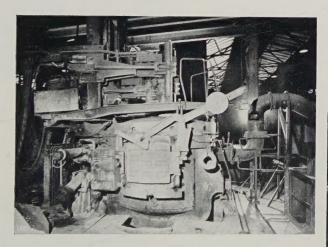
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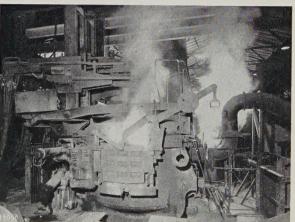
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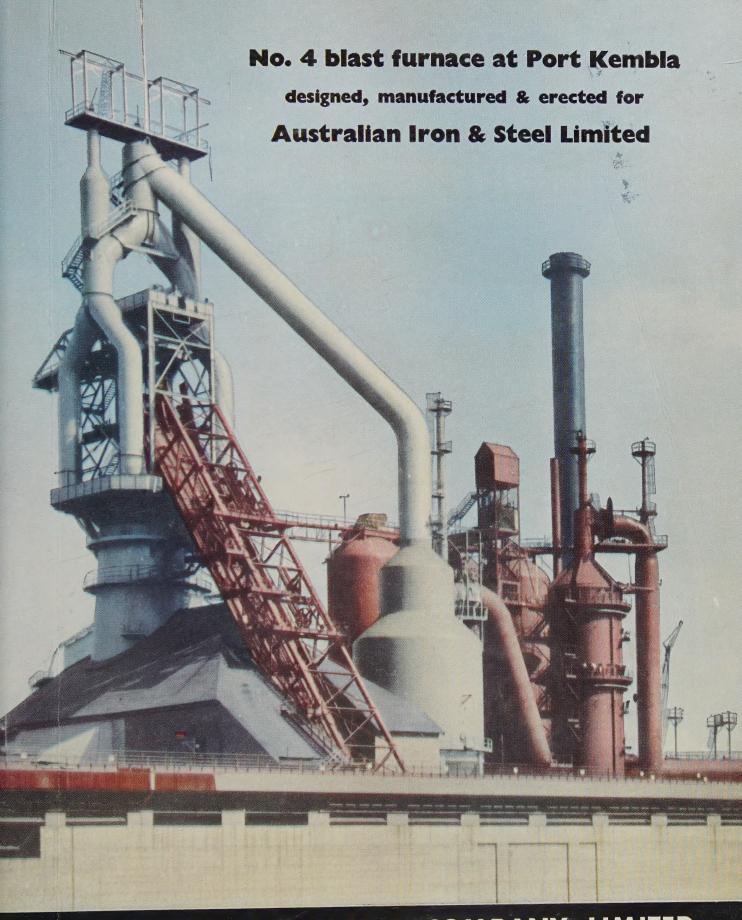
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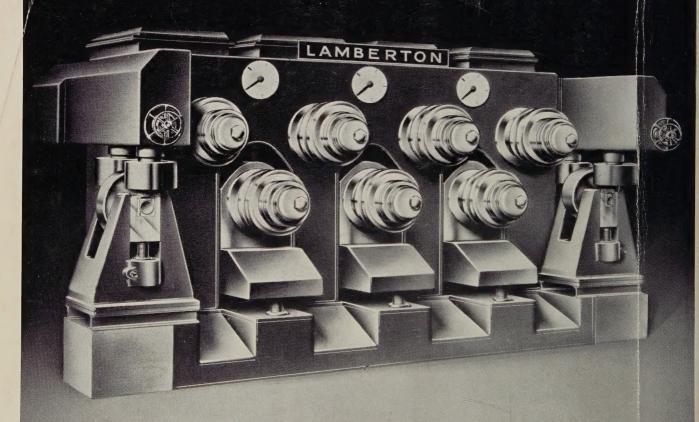
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